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Structural Dynamics Division Research and Technology Accomplishments for F.Y. 1993 and Plans for F.Y. 1994

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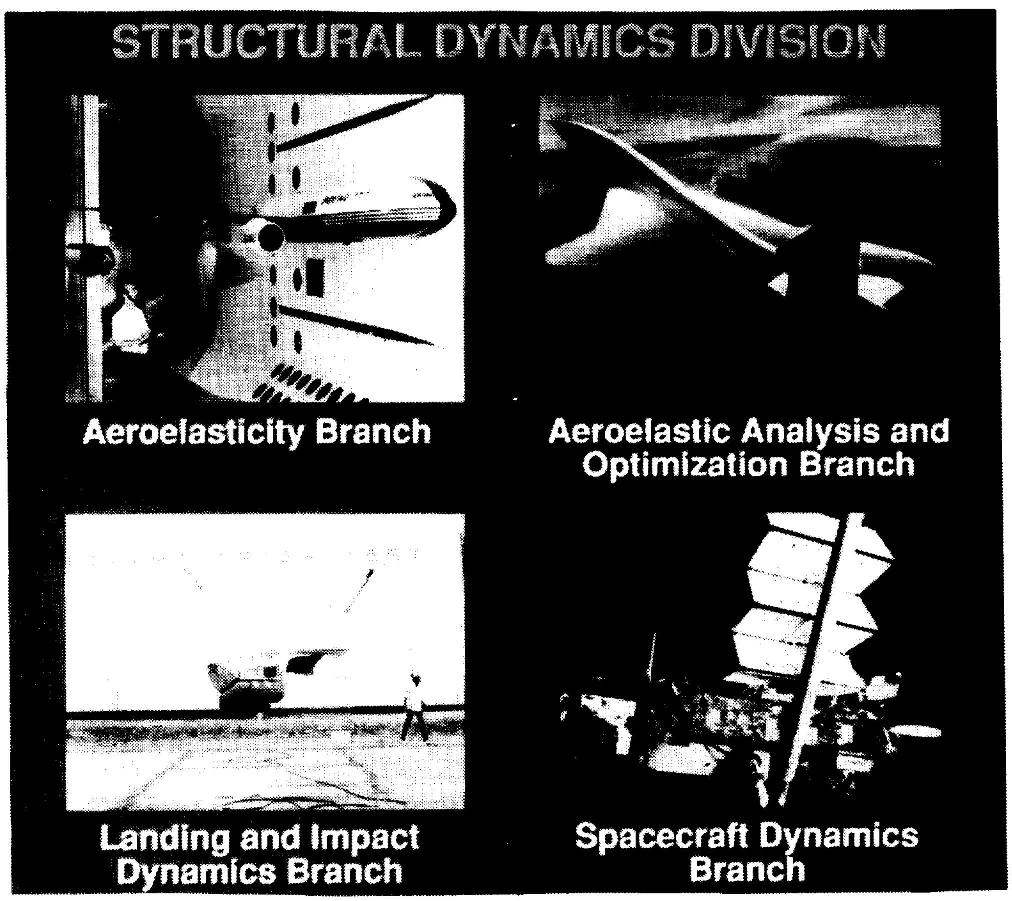

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STRUCTURAL DYNAMICS DIVISION

RESEARCH AND TECHNOLOGY ACCOMPLISHMENTS FOR F.Y. 1993

AND PLANS FOR F.Y. 1994

SUMMARY

The purpose of this paper is to present the Structural Dynamics Division's research accomplishments for F.Y. 1993 and research plans for F.Y. 1994. The work under each branch/office (technical area) is described in terms of highlights of accomplishments during the past year and plans for the current year as they relate to 5-year plans and the objectives for each technical area. This information will be useful in program coordination with other government organizations, universities, and industry in areas of mutual interest.

ORGANIZATION

The Langley Research Center was organized into directorates in fiscal year 1993 as shown in figure 1. Directorates were subdivided into divisions and offices. The Structural Dynamics Division of the Structures Directorate consists of four branches as shown in figure 2. This figure lists the key people in the Division which consists of 72 NASA civil servants and 14 U. S. Army civil servants of the Vehicle Structures Directorate, U. S. Army Research Laboratory, collocated at the Langley Research Center. Phone numbers for each organization are given. Each branch represents a technical area and focused activities under the technical areas are shown in the figure.

The Division conducts analytical and experimental research in four technical areas to meet technology requirements for advanced aerospace vehicles. The research thrusts are given in figure 3. The Aeroelasticity Branch (AB), and the Aeroelastic Analysis and Optimization Branch (AAOB) work in the areas of the prediction and control of aeroelastic stability and response of aircraft, rotorcraft, space launch vehicles; and methodology for aerospace vehicle design. The latter's emphasis is on providing analytical methods to quantify interactions among engineering disciplines and to exploit this interaction for improved performance. The Landing and Impact Dynamics Branch (LIDB) conducts research on the crash dynamics of aircraft structures and on the technology for improving the safety and handling performance of aircraft during ground operations. The Spacecraft Dynamics Branch (SDB) conducts research on the prediction and control of the structural dynamic response of complex space structures.

FUNCTIONAL STATEMENT

The Division conducts analytical and experimental research in the areas of configuration aeroelasticity, aeroservoelasticity, unsteady aerodynamics, impact and landing dynamics, spacecraft dynamics, and multidisciplinary design to meet technology requirements for advanced atmospheric and space flight vehicles. It also develops analytical and computational methods for predicting and controlling aeroelastic instabilities, deformations, vibrations, and dynamic response. The Structural Dynamics Division investigates the interaction of structure with aerodynamics and control systems, landing dynamics, impact dynamics, and resulting structural response. It evaluates structural configurations embodying new material systems and/or advanced design concepts for general application and for specific classes of new aerospace vehicles. The Division develops methodology for aircraft and spacecraft design using integrated multidisciplinary methods. A broad spectrum of test facilities to validate analytical and computational methods and advanced configuration and control concepts are used. Research techniques to demonstrate safety from aeroelastic instabilities for new airplanes, helicopters, and space launch vehicles are developed. Test facilities include the Transonic Dynamics Tunnel, the Helicopter Hover Facility, the Impact Dynamics Research Facility, the Aircraft Landing Dynamics Facility, the Space Structures Research Laboratory, and the Structural Dynamics Research Laboratory.

FACILITIES

The Structural Dynamics Division has four major facilities available to support its research as shown in figure 4.

The Transonic Dynamics Tunnel (TDT) is a maximum Mach 1.2 continuous flow, variable pressure wind tunnel with a 16-square-foot test section which uses either air or heavy gas (R-12) as the test medium. The maximum Reynolds number obtainable is approximately 10 million per foot in heavy gas and 3 million per foot in air. The TDT is a unique "National" facility that is used almost exclusively for testing of aeroelastic phenomena. Semi-span, sidewall-mounted models and full-span, sting-mounted or cable-mounted models are used for aeroelastic studies of fixed wing aircraft. In addition, the Aeroelastic Rotor Experimental System (ARES) test stand is used in the tunnel to study the aeroelastic characteristics of rotor systems. The Helicopter Hover Facility (HHF), located in an adjacent building, is used to set up the ARES test stand in preparation for entry into the TDT and for rotorcraft studies in hover. The TDT Data Acquisition System is capable of simultaneous support of tunnel tests, HHF tests and model checkout in the Calibration Lab. Over the summer of 1993 the TDT was shut down from normal production operations due to severe pipe vibrations and associated safety hazards. These problems were solved and the tunnel is now in an operational status. A study has been underway and is now nearing completion to choose a replacement heavy gas test medium for the TDT.

The Aircraft Landing Dynamics Facility (ALDF) is capable of testing various types of landing gear systems at velocities up to 220 knots on a variety of runway surfaces under many types of simulated weather conditions. The ALDF consists of a 2800-foot-long rail system, a 2.2 million pound thrust propulsion system, a test carriage, and an arresting system. Test articles can be subjected to vertical loads up to 65,000 pounds and sink rates up to 20 feet per second on a variety of runway surface conditions. The facility provides for testing at speeds and sizes pertinent to large transport aircraft, fighter aircraft, and the Space Shuttle Orbiter.

The Impact Dynamics Research Facility (IDRF), which was originally used by the astronauts during the Apollo program for simulation of lunar landings, has been modified to simulate crashes of full-scale aircraft under controlled conditions. The aircraft are swung by cables from an A-frame structure which is approximately 400 feet long and 230 feet high. The impact runway can be modified to simulate other ground crash environments, such as packed dirt, to meet a specific text requirement. Each aircraft is suspended by cables from two pivot points 217 feet off the ground and allowed to swing, pendulum-style, into the ground. The swing cables are separated from the aircraft by pyrotechnics just prior to impact. Length of the swing cables regulates the aircraft impact angle from 0 degrees (level) to approximately 60 degrees. Impact velocity can be varied to approximately 65 mph (governed by the pullback height). Variations of aircraft pitch, roll, and yaw can be obtained by changes in the aircraft's suspension harness attached to the swing cables. Onboard instrumentation data are obtained through an umbilical cable which is hard-wired to the control room at the base of the A-frame. Photographic data are obtained by onboard, ground-mounted, and A-frame mounted cameras. Maximum allowable weight of the aircraft is 30,000 lbs.

Building 1293 facilities are uniquely designed to carry out structures-related research on spacecraft and aircraft structures, equipment, and materials. Recent emphasis on testing capability at low frequencies has allowed the characterizing of spacecraft and high-gain control systems needed to meet pointing requirements. The heights of the labs allow properly suspended models with reduced effects of gravity and the sizes allow simultaneous tests of large structures over long periods of time. It offers controlled environmental conditions including acceleration, thermal radiation, vacuum and several shaker types for actuation and excitation. All areas are television monitored and hard-wired to data acquisition and processing equipment. A 256-channel digital data acquisition and signal processing system is available with on-line test controllers. A variety of auxiliary data logging and signal processing equipment is also available.

The 16-meter Thermal Vacuum Chamber has a 55-foot diameter cylinder, a 64-foot-high hemispherical dome peak, a flat floor and a rotation option of a centrifuge arm or table. The centrifuge is rated at 20,000 lbs, up to 100g, with a 50,000-force-lb capacity and a maximum allowable specimen weight of 2,000 lbs. Access is by two doors; one 20 x 20 feet. A vacuum of 10 microns Hg can be achieved in 220 minutes. Temperature gradients of 100-^{o}F are obtained from 250-ft^2 of portable radiant heaters and liquid nitrogen cooled plates.

The Structural Dynamics Research Laboratory is dominated by a 38-foot-high backstop. Test areas available around this backstop are 15 x 35 x 38 feet high and 12 x 12 x 95 feet high. Access to the entire lab is provided by spiral stairs, ladders, and platforms.

The Space Structures Research Laboratory (SSRL) is a large open room of 5200-ft^2. There is a work platform 73 feet above the floor with removable decking and a 20 x 30 x 40-foot free-standing gantry for isolated suspension. In one corner there is a vertical 12 x 12-foot backstop. There is a full environmental control system and many platforms accessible for viewing and instrumentation. The control room contains a state-of-the-art data acquisition capability and overlooks the laboratory. The laboratory houses controls-structures interaction models, including the Controls-Structures Evolutionary Model, for performing structural dynamics and controls research of space structures.

F. Y. 1993 ACCOMPLISHMENTS

Aeroelastic Analysis and Optimization Branch

(Pages 25-41)

The Aeroelastic Analysis and Optimization Branch, (AAOB), (fig. 5) develops methodology for aircraft design that will provide a means to understand and to quantify interactions among different engineering disciplines in order to control and exploit these interactions for improved vehicle performance and increased efficiency of the design process. Branch members conduct research to accomplish the goals: develop, apply, and validate through experiments, analytical and computational methods for predicting steady and unsteady aerodynamic loads and aeroelastic characteristics of flight vehicles, with emphasis on the transonic speed range; develop design methodology, including algorithms and strategies for optimization and for sensitivity analysis; develop and demonstrate methods for controlling aeroelastic instabilities. Wind tunnel tests are conducted to verify and validate the accuracy of unsteady aerodynamic calculations and aeroelastic stability predictions. Present activities and plans for the major activity areas are presented in figure 6.

The Aeroelastic Analysis and Optimization Branch F.Y. 1993 accomplishments listed below are highlighted in figures 7 through 12.

Aeroelastic Analysis and Validation:

- Low-Speed Turbulence Measurements of Air Flow in the Transonic Dynamics Tunnel
- Transonic Shock Oscillation Onset Phenomena Demonstrated Computationally

Control Law Design and Analysis:

- Robustness Analysis Methodology for a Multirate Flutter Suppression System Developed

Rotorcraft Optimization:

- Coupling of Structures to Aerodynamic/Dynamic Optimization Assures Viability of Rotor Blades

Aircraft Optimization:

- Multidisciplinary Design Optimization Improves Performance for HSCT Study Configuration
- Dissemination and Applications of the Design Manager's Aid for Intelligent Decomposition (DeMAID)

Aeroelasticity Branch

(Pages 43-57)

The Aeroelasticity Branch (AB) (fig. 13) conducts research to develop the understanding of aeroelastic phenomena and prediction capabilities needed to apply new aerodynamic and structural concepts to future flight vehicles and to determine and solve the aeroelastic problems of current designs. The AB develops and validates advanced control concepts that employ smart materials or aerodynamic control surfaces for suppressing aeroelastic response and alleviating loads and vibration. It conceives, recommends, and provides technical support for ground testing, simulations, wind-tunnel tests, and flight experiments to validate the methodologies. The AB evaluates the aeroelastic characteristics of new rotor systems through wind-tunnel tests and analysis and determines effective means for reducing helicopter vibrations. It generates mathematical models required to support NASA flight projects and performs studies to verify theoretical developments involving advanced control concepts. The AB participates in flutter prevention programs for new vehicles by use of analysis and aeroelastically scaled model tests. It operates the Transonic Dynamics Tunnel and the Helicopter Hover Facility. The scope of this work is more explicitly identified in figure 14 which shows the AB 5-year plan.

The Aeroelasticity FY 1993 accomplishments listed below are highlighted in figures 15 through 20.

Wind-Tunnel Tests

- Transonic Aeroelastic Characteristics Determined for Modern Transport Design in TDT
- Flutter Study of Simple Business-Jet Wing Conducted in TDT for Gulfstream
- Flutter Characteristics of a Full-Span NASP Model Determined in TDT
- TDT Tests Conducted to Evaluate Advanced Rotor Blade Technology

Theoretical Developments

- Algorithm Developed for the FAA That Computes Design Gust Loads for Nonlinear Aircraft
- Bending-Twist-Coupled Rotor Blade Improves Tiltrotor Stability

Landing and Impact Dynamics Branch

(Pages 59-71)

The Landing and Impact Dynamics Branch (fig. 21) operates two major facilities, the Aircraft Landing Dynamics Facility (ALDF) for experimental studies of aircraft landing gear systems and components and the Impact Dynamics Research Facility (IDRF) for experimental investigations of the crash response characteristics of metal and composite airframe structures. The landing dynamics group is responsible for research activities aimed at improving the technology needed to assure safe, economical all-weather ground operations and the development of new landing gear systems and concepts. The group coordinates in-house research, grant activities, contract efforts, and joint government-industry programs to achieve the required technology. The impact dynamics group conducts research to obtain a better understanding of the response characteristics of composite airframe components subjected to crash loads and to develop and enhance analytical tools for predicting these response characteristics and for providing insights into the fundamental physics associated the structural behavior of these airframe components. In-house research, grant efforts, and contract activities are utilized to develop structural concepts that exhibit superior energy absorption characteristics that result in reduced crash loads and to develop the technology needed to analyze these structural responses. The work of the Landing and Impact Dynamics Branch is more clearly identified in figure 22 which shows the 5-year plans for the disciplines in both landing and impact dynamics along with their expected results.

The Landing and Impact Dynamics Branch F. Y. 1992 accomplishments are highlighted in figures 23 through 27.

Impact Dynamics

- Composite Scaling Studies Provide a variety of Important Spin-Offs
- Energy Absorbing Characteristics of a Composite Fuselage Section Defined
- Improved Safety of Helicopter Fuel Bladders

Landing Dynamics

- H46 X 18-20 Bias-Ply and Radial-Belted Tire Characteristics Defined
- Effects of Type II De-Icer Fluid on Aircraft Tire Friction Determined in ALDF Tests

Spacecraft Dynamics Branch

(Pages 72-81)

The Spacecraft Dynamics (fig. 28) conducts research and focused technology studies on the dynamics and control of flexible spacecraft. Integrating structure and control systems in control law design and analysis, performance prediction and control methods are developed for application to Earth-observing science spacecraft, Space Station, and commercial spacecraft. Methods are verified and improved through experiments on research hardware. Advanced test and data analysis methods for improving the accuracy and speed of ground tests to simulate on-orbit behavior and/or to verify spacecraft and spacecraft components for flight are also developed. Significant ongoing emphasis is on the design of interdisciplinary experiments for the on-orbit dynamic characterization and instrument jitter risk reduction of the EOS family of spacecraft. On-orbit verification of methods via experiments is a long-term goal and advanced algorithms for system identification are being developed for that application. The scope of this work is more explicitly identified in figure 29 which shows the 5-year plan of the organization's major thrusts and their expected result.

The Spacecraft Dynamics Branch F.Y. 1993 accomplishments listed below are highlighted in figures 30 through 33.

Controls-Structures Interaction:

- Spacecraft Size Affects Pointing Performance
- Martin Marietta Viscoelastic Damper Strut Testing on the Phase-2 CEM Testbed

Base Research:

- Eigensystem Realization Algorithm (ERA) Meeting NASA and Industry Dynamic Testing Needs
- State Space Frequency Domain Identification Tools

PUBLICATIONS

The F. Y. 1993 accomplishments of the Structural Dynamics Division resulted in a number of publications. The publications are listed below by organization in the categories of journal publications, formal NASA reports, conference presentations, contractor reports, technical briefs, and patents.

Division Office

Journal Publications:

1. Sobieszczanski-Sobieski, J.: Optimization by Decomposition. AIAA Educational Series, Vol. 150, 1993, pp. 487-515.

Formal NASA Reports:

2. Sobieszczanski-Sobieski, J.: Multidisciplinary Design Optimization: An Emerging New Engineering Discipline. NASA TM 107761, May 1993, 12 p.

3. Wynne, E. C.: Structural Dynamics Division Research and Technology Accomplishments for F.Y. 1992 and Plans for F.Y. 1993. NASA TM 107713, January 1993, 227 p.

Conference Presentations:

4. Abel, I.: Recent Research and Applications in Structural Dynamics and Aeroelasticity at the NASA Langley Research Center. Presented at the International Forum on Aeroelasticity and Structural Dynamics 1993, Strasbourg, France, May 24-26, 1993. In Proceedings.

5. Doggett, R. V. Jr.; Rosser, D. C. Jr.; and Bryant, C. S.: Data Acquisition for Aeroelastic Testing at the NASA Langley Transonic Dynamics Facility. Presented at the 39th International Instrumentation Symposium, Albuquerque, New Mexico, May 2-6, 1993. In Proceedings, pp. 877-887.

6. Ricketts, R.; Noll, T.; Whitlow, W.; Huttsell, L.: An Overview of Aeroelasticity Studies for the National Aerospace Plane. Presented at the AIAA/ASME/ASCE/AHS/ASC 34th Structures, Structural Dynamics, and Materials Conference, LaJolla, California, April 1993. AIAA Paper No. 93-1313. Also published as NASA TM 107728, March 1993, 12 p.

7. Sobieszczanski-Sobieski, J.: Multidisciplinary Design Optimization: An Emerging New Engineering Discipline. Presented at the Structural Optimization 93, Rio de Janeiro, Brazil, August 2-6, 1993. In Proceedings.

Aeroelastic Analysis and Optimization Branch

Journal Publications:

8. Adelman, Howard M.; and Haftka, Raphael T.: Sensitivity Analysis of Discretely Modeled Structures. Structural Optimization: Status and Promise, M. Kamat, ed. AIAA Vol. 50, Progress in Astronautics and Aeronautics, 1993, pp. 291-315.

9. Batina, J. T.: Implicit Upwind Solution Algorithms for Unstructured-Grid Applications, AIAA Journal, Vol. 31, No. 5, May 1993, pp. 801-805.

10. Chang, K. J.; Haftka, R. T.; Giles, G. L.; and Kao, P-J.: Sensitivity-Based Scaling for Approximating Structural Response, Journal of Aircraft, Vol. 30, No. 2, March-April 1993, pp. 283-288.

11. Dunn, H. J.: Experimental Results of Active Control on a Large Structure to Suppress Vibration. Journal of Guidance, Control, and Dynamics, Vol. 15, No. 6, November-December 1992, pp. 1334-1342.

12. Lee, E. M.; and Batina, J. T.: Results from a Conical Euler Methodology Developed for Unsteady Vortical Flows, AIAA Journal, Vol. 31, No. 5, May 1993, pp. 818-819.

13. Padula, S. L.; and Sandridge, C: Passive/Active Strut Placement by Integer Programming, Topology Design of Structures, Bendsoe and Mota Soares, ed. Kluwer Academic Publishers, pp. 145-156.

14. Silva, W. A.: Application of Nonlinear Systems Theory to Transonic Unsteady Aerodynamic Responses, Journal of Aircraft, Vol. 30, No. 5, September-October 1993, pp. 660-668.

15. Walsh, J. L.; LaMarsh, W. J. II; and Adelman, H. M.: Fully Integrated Aerodynamic/ Dynamic Optimization of Helicopter Rotor Blades, Mathematical and Computer Modelling, Vol. 18, No. 3/4, 1993, pp. 53-72.

Formal NASA Reports:

16. Adams, W.; Christhilf, D.; Waszak, M.; Mukhopadhyay, V.; and Srinathkumar, S.: Design, Test, and Evaluation of Three Active Flutter Sppression Controllers. NASA TM 4338, October 1992.

17. Lee-Rausch, Elizabeth M.; and Batina, John T.: Conical Euler Analysis and Active Roll Suppression for Unsteady Vortical Flows About Rolling Delta Wings. NASA TP 3259, March 1993.

18. Rogers, J. L. Jr.; LaMarsh, W. J. II; Hill, J. S.; and Bradley, D. E.: Applications of a Neural Network as a Potential Aid in Predicting NTF Pump Failure. NASA TM 107667, January 1993, 11 p.

Conference Presentations:

19. Batina, J. T.: A Gridless Euler/Navier-Stokes Solution Algorithm for Complex-Aircraft Applications. Presented at the AIAA 31st Aerospace Sciences Meeting, Reno, Nevada, January 11-14, 1993. AIAA Paper No. 93-0333.

20. Eldred, L. B.; Kapania, R. K.; and Barthelemy, J-F.: Sensitivity Analysis of Aeroelastic Response of a Wing Using Piecewise Pressure Representation. Presented at the AIAA/ASME/ASCE/AHS/ASC 34th Structures, Structural Dynamics, and Materials Conference, LaJolla, California, April 19-22, 1993. AIAA Paper No. 93-1645.

21. Lee-Rausch, Elizabeth M.; and Batina, John T.: Wing Flutter Boundary Prediction Using Unsteady Euler Aerodynamic Methods. Presented at the AIAA/ASME/ASCE/AHS/ASC 34th Structures, Structural Dynamics, and Materials Conference, LaJolla, California, April 19-21, 1993. AIAA Paper No. 93-1422. Also published as NASA TM 107732, March 1993.

22. Lee-Rausch, Elizabeth M.; and Batina, John T.: Calculation of AGARD Wing 445.6 Flutter Using Navier-Stokes Aerodynamics. Presented at the AIAA 11th Applied Aerodynamics Conference, Monterey, California, August 9-11, 1993. AIAA Paper No. 93-3476.

23. Rausch, R. D.; Batina, J. T.; and Yang, H. T. Y.: Spatial Adaption Procedures on Tetrahedral Meshes for Unsteady Aerodynamic Flow Calculations. Presented at the AIAA 31st Aerospace Sciences Meeting, Reno, Nevada, January 11-14, 1993. AIAA Paper No. 93-0670. Also published as NASA TM 107726, February 1993, 14 p.

24. Silva, Walter A.: Extension of a Nonlinear Systems Theory to General Frequency Unsteady Transonic Aerodynamic Responses. Presented at the AIAA/ASME/ASCE/ AHS/ASC 34th Structures, Structural Dynamics, and Materials Conference, LaJolla, California, April 19-21, 1993. AIAA Paper No. 93-1590.

25. Silva, Walter A.: Modeling Transonic Aerodynamic Response Using Nonlinear Systems Theory for Use with Modern Control Theory. Presented at the NASA LaRC Workshop on Guidance, Navigation, Control, and Dynamics for Atmospheric Flight, March 18-19, 1993. NASA CP 10127.

26. Sleeper, R.; Keller, D.; Perry, B.; and Sandford, M.: Vertical and Lateral Gust Components Measurements in the Transonic Dynamics Tunnel Using a Hot-Film Anemometer with an X-Probe. Presented at the Forum on Fluid Measurements and Instrumentation, Washington, DC, June 1993. Also published as NASA TM 107734, March 1993.

27. Whitlow, Woodrow Jr.: Research in Unsteady Aerodynamics and Computational Aeroelasticity at the NASA Langley Research Center. Presented at the International Forum on Aeroelasticity and Structural Dynamics 1993, Strasbourg, France, May 24-26, 1993. In Proceedings.

Contractor Reports:

28. Carpenter, W. C.: Effect of Design Selection on Response Surface Performance. (NAG1-1378, University of South Florida.) NASA CR-4520, June 1993, 180 p.

29. James, B. B.: Multidisciplinary Optimization of a Controlled Space Structure Using 150 Design Variables. (NAS1-19000, Lockheed Engineering Sciences Company.) NASA CR-4502, February 1993, 20 p.

30. Jin, I. M.; and Schmit, L. A.: Control Design Variable Linking for Optimization of Structural/Control Systems. NASA CR-4493, February 1993, 184 p.

Computer Programs:

31. Rogers, J. L. Jr.; and Hall, L. E.: DeMAID: A Design Manager's Aid for Intelligent Decomposition (IRIS Version of DeMAID). Computer Program LAR-15099.

Aeroelasticity Branch

Journal Publications:

32. Heeg, J.; Gilbert, M. G.; Pototzky, A. S.: Active Control of Aerothermoelastic Effects for a Conceptual Hypersonic Aircraft. AIAA Journal of Aircraft, Vol. 30, No. 4, July-August 1993, pp. 453-458.

33. Scott, R.; Pototzky, A.; Perry, B.: Computation of Maximized Gust Loads for Nonlinear Aircraft Using Matched Filter Based Schemes. Journal of Aircraft, Vol. 30, No. 5, September-October 1993, pp. 763-768.

34. Yeager, W. T. Jr.; Mirick, P. H.; Hamouda, M-N. H.; Wilbur, M. L.; Singleton, J. D.; Wilkie, W. K.: Rotorcraft Aeroelastic Testing in the Langley Transonic Dynamics Tunnel. Journal of the American Helicopter Society, Vol. 38, No. 3, July 1993, pp. 73-82.

Formal NASA Reports:

35. Dansberry, B. E.; Durham, M. H.; Bennett, R. M.; Turnock, D. L.; Silva, W. A.; Rivera, J. A. Jr.: Physical Properties of the Benchmark Models Program Supercritical Wing. NASA TM 4457, September 1993.

36. D'Cruz, J.: A Determination of the External Forces Required to Move the Benchmark Active Controls Testing Model in Pure Plunge and Pure Pitch. NASA TM 107743, July 1993.

37. Heeg, J.: An Analytical and Experimental Study to Investigate Flutter Suppression Via Piezoelectric Actuation. NASA TP 3241, March 1993.

38. Lake, R.; Izadpanah, A.; Baucom, R.: Experimental and Analytical Investigation of Dynamic Characteristics of Extension-Twist-Coupled Composite Tubular Spars. NASA TP 3225, February 1993.

Conference Presentations:

39. Adams, W.; Hoadley, S.: ISAC - A Tool for Aeroservoelastic Modeling and Analysis. Presented at the AIAA/ASME/ASCE/AHS/ASC 34th Structures, Structural Dynamics, and Materials Conference, LaJolla, California, April 1993. AIAA Paper No. 93-1421.

40. Cole, Stanley R.; Florance, James R.; Spain, Charles V.; and Bullock, Ellen P.: Measured and Predicted Supersonic Divergence Conditions for a NASP-Like Wing Model. Presented at the 1993 NASP Technology Review, Monterey, California, April 1993. Paper No. 11. Also published in NASP CP-12079.

41. Cole, Stanley R.; Florance, James R.; Thomason, Lee B.; Spain, Charles V.; Bullock, Ellen P.: Supersonic Aeroelastic Instability Results for a NASP-Like Wing Model. Presented at the AIAA/ASME/ASCE/AHS/ASC 34th Structures, Structural Dynamics, and Materials Conference, LaJolla, California, April 1993. AIAA Paper No. 93-1369. Also published as NASA TM 107739, April 1993.

42. Dansberry, B.; Durham, M.; Bennett, R.; Rivera, J.; Turnock, D.; Silva, W.; Wieseman, C.: Experimental Unsteady Pressures at Flutter on the Supercritical Wing Benchmark Model. Presented at the AIAA/ASME/ASCE/AHS/ASC 34th Structures, Structural Dynamics, and Materials Conference, LaJolla, California, April 1993. AIAA Paper No. 93-1592.

43. D'Cruz, J: On the Identification of a Harmonic Force on a Viscoelastic Plate from Response Data. Presented at the 1992 ASME Winter Annual Meeting, Anaheim, California, November 1992.

44. Durham, M.: The Benchmark Models Program - Status and Future Plans. Presented at the Aerospace Flutter and Dynamics Council Meeting, Lancaster, California, May 1993.

45. Heeg, J.; Miller, J.; Doggett, R.: An Experimental Study of Buffet Load Alleviation Using Piezoelectric Actuators. Presented at the SPIE 1993 North American Conference on Smart Structures and Materials, Albuquerque, New Mexico, February 1993.

46. Heeg, J.; Miller, J.; Doggett, R.: Attenuation of Empennage Buffet Response Through Active Control of Damping Using Piezoelectric Material. Presented at the Damping '93, San Francisco, California, February 1993. Also published as NASA TM 107736, February 1993.

47. Heeg, J.; Zeiler, T.; Pototzky, A.; Spain, V.; Engelund, W.: Aerothermoelastic Analyses of a NASP Demonstrator Model. Presented at the 1993 NASP Technology Review, Monterey, California, April 1993. Paper No. 128. Also published in NASP CP-12079. Also presented at the AIAA/ASME/ASCE/AHS/AASC 34th Structures, Structural Dynamics, and Materials Conference, LaJolla, California, April 1993. AIAA Paper No. 93-1366.

48. Hoadley, S.; Wieseman, C.; McGraw, S.: Multiple-Function Multi-Input/Multi-Output Digital Control and On-line Analysis. Presented at the DSP^{X} Exposition

and Symposium, San Jose Convention Center, San Jose, California, October 1992. Also published as NASA TM 107697, October 1992.

49. Huttsell, L. J.; Sallee, V. J.; Bullock, E. P.; Cole, S. R.: Analytical and Experimental Panel Flutter Results. Presented at the 1993 NASP Technology Review, Monterey, California, April 1993. Paper No. 12. Also published in NASP CP-12079.

50. Noll, T.; Sparrow, J.; Lee, B.; Kaynes, I.; Graham, G.; Harris, T.; Austin, E.; Donley, S.: Impact of Active Control Technology on the Structural Integrity of Aeronautical Vehicles. Presented at the AGARD Structures and Materials Panel Meeting, Lindau, Germany, October 4-9, 1992.

51. Paige, D.; Scott, R.; Weisshaar, T.: Composite Panel Flutter Suppression Using Adaptive Materials. Presented at the SPIE 1993 North American Conference on Smart Structures and Materials, Albuquerque, New Mexico, February 1993.

52. Perry, B.; Scott, R.; Pototzky, A.: Update of NASA Research in Time Correlated Gust Loads for Nonlinear Aircraft - Matched Filter Based and Stochastic Simulation Based Methods. Presented at the Gust Specialists Meeting, LaJolla, California, April 1993.

53. Scott, R.; Perry, B.; Pototzky, A.: Further Studies Using Matched Filter Theory and Stochastic Simulation for Gust Loads Prediction. Presented at the AIAA/ASME/ASCE/ AHS/ASC 34th Structures, Structural Dynamics, and Materials Conference, LaJolla, California, April 1993. AIAA Paper No. 93-1365. Also published as NASA TM 109010, July 1993.

54. Scott, R.; Pototzky, A.: A Method of Predicting Quasi-Steady Aerodynamics for Hypersonic Flutter Analysis Using Steady CFD Calculations. Presented at the 1993 NASP Technology Review, Monterey, California, April 1993. Paper No. 130. Also published in NASP CP-12079.

55. Scott, R.; Pototzky, A.: A Method of Predicting Quasi-Steady Aerodynamics for Hypersonic Flutter Analysis Using Steady CFD Calculations. Presented at the AIAA/ ASME/ASCE/AHS/ASC 34th Structures, Structural Dynamics, and Materials Conference, LaJolla, California, April 1993. AIAA Paper No. 93-1364. Also published as NASA TM 109009, July 1993.

Technical Briefs:

56. Hoadley, S.: Program Estimates Unsteady Aerodynamic Forces. NASA Tech Brief LAR-14893.

57. Rivera, J. Jr.: Continuous-Surface Deformable Aeroelastic Models. NASA Tech Brief LAR-14792.

Landing and Impact Dynamics Branch

Journal Publications:

58. Jackson, Karen E.; Kellas, Sotiris; and Morton, J.: Scale Effects in the Response and Failure of Fiber Reinforced Composite Laminates Loaded in Tension and in Flexure. Journal of Composite Materials, Vol. 26, No. 18, 1992, pp. 2674-2705.

Conference Presentations:

59. Carden, Huey D.; and Kellas, Sotiris: Energy-Absorbing-Beam Design for Composite Aircraft Subfloors. Presented at the AIAA/ASME/ASCE/AHS/ASC 34th Structural Dynamics, and Materials Conference, LaJolla, California, April 19-21, 1993. AIAA Paper No. 93-1339.

60. Daugherty, Robert H.: The Effect of Runway Surface and Braking on Shuttle Orbiter Main Gear Tire Wear. Presented at the SAE Aerotech '92 Conference, Anaheim, California, October 5-8, 1992. SAE Technical Paper 922035.

61. Davis, Pamela A.: F-4 Bias-Ply and Radial-Belted Tire Analysis. Presented at the SAE Aerotech '92 Conference, Anaheim, California, October 5-8, 1992. SAE Technical Paper 922012.

62. Davis, Pamela A.: NASA Langley's Aircraft Landing Dynamics Facility. Presented at the 39th International Instrumentation Symposium, Albuquerque, New Mexico, May 2-6, 1993. Paper No. 93-134, pp. 915-947.

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F. Y. 1994 PLANS

Aeroelastic Analysis and Optimization Branch
(Page 82)

Figure 34 outlines the F. Y. 1994 plans for the Aeroelastic Analysis and Optimization Branch (AAOB). Researchers will continue to support the Benchmark Models Program (BMP). This includes continuing the role of lead organization for the rigid High Speed Civil Transport (HSCT) model and designing a modified pitch-and-plunge apparatus mount system, continuing the lead role for a model with NACA 64A010 airfoil sections, and providing support for testing other models and analyzing the resulting data. Other support of the BMP will be to characterize the turbulence in the Transonic Dynamics Tunnel; this is necessary for design of control systems for the Benchmark Active Controls Technology model. In the area of aeroelastic analysis methods development, AAOB researchers plan to develop a gridless computational fluid dynamics method for aeroelastic predictions, and a method for incorporating nonlinear aerodynamics in aeroservoelastic analysis and design will be developed. Development of methods to interact boundary layer methods with inviscid flow codes will continue, and such methods will be applied to cases of transonic limit cycle oscillations.

In the area of rotorcraft optimization, automatic differentiation will be coupled with analysis methods to perform sensitivity analysis of helicopter rotor blade performance for hovering vehicles. Acoustics effects will be included in the optimization of rotor blade performance, and a procedure to minimize the effects of uncertainties in loads and properties will be developed.

In the area of the aircraft optimization, an integrated design problem for an HSCT configuration will be formulated. This research area also supports the High Performance Computing and Communication Program (HPCCP), and the branch will develop methods for enhancing the Framework for Interdisciplinary Design Optimization system that is part of the HPCCP. A method for computing flutter speed sensitivity to structural and shape variables has been under development, and it will be demonstrated in F. Y. 1994. The AAOB program will support the development of a method for integrated design of a structure-control system to minimize sensitivity to uncertainties.

Aeroelasticity Branch
(Page 83)

Figure 35 lists the major tasks being pursued by the Aeroelasticity Branch (AB) in F.Y. 1994. A wide variety of aeroelastic tests for many customers are planned for the Transonic Dynamics Tunnel (TDT). Over the course of the year TDT tests will support the Department of Defense, the National Aerospace Plane (NASP) and High Speed Civil Transport (HSCT) projects, and the U.S. business jet industry, as well as supporting a cooperative program with the Massachusetts Institute of Technology and in-house research programs. The in-house programs include the Benchmark Models Program and rotorcraft aeroelasticity research using the Aeroelastic Rotor Experimental System (ARES) testbed.

F.Y. 1994 plans also include the refurbishment of two aeroelastic wind-tunnel models for eventual testing in the TDT in support of two focussed programs: HSCT and

ST(CT). The first is a full-span flexible model of a supersonic transport configuration; the second, an aeroelastic model of the V-22 tiltrotor configuration.

There are plans underway to convert the TDT to an alternate heavy gas and to begin implementation of the next generation UNIX-based ModComp data acquisition system.

Landing and Impact Dynamics Branch

Page (84)

During F. Y. 1994 a major focused technology activity in the area of landing dynamics will be the development of advanced active control landing gear concepts for HSCT applications. Components of this activity include in-house research on a smart orifice concept using F-106 landing gear hardware using the newly acquired "runway simulator" shaker table, grant activities to study the chemical characteristics of electrorheological fluids and to develop an electrorheological damper concept for possible applications to active control landing gear technology, and a contract activity to develop analysis tools for active control landing gear studies. The smooth runway testing of the H-Type 46 x 18-20 bias-ply and radial belted aircraft tires on ALDF, requested by airframe manufacturers will be completed this year. Tire footprint force measurements on various tire sizes will be conducted using two Tire Footprint Force Transducers. Additional testing on ALDF will evaluate the friction characteristics of bias-ply and radial-belted F-4 main gear tires, define the friction characteristics of several paver block concepts, and investigate the friction performance of various tire sizes and constructions on grooved concrete surfaces. The branch tire modeling activities will continue with the development of advanced frictional contact algorithms. A new study of the characteristics of pavement surfaces using fractical geometry concepts will be initiated this year as a grant activity.

The major focused technology activity in the impact dynamics area is associated with the Advanced Composite Technology (ACT) Program. In this area a task assignment contract will provide composite test specimens for nondestructive and crash tests. A new initiative in general aviation crash dynamics is planned. A design support test effort will be completed to provide an energy absorbing general aviation subfloor concept. The concept will be fabricated and installed in a fuselage section and eventually in a Lear Fan airplane. Strength scaling studies of composite structures using a ply scaling approach and failure studies with composite fuselage frames will be completed. Full-scale testing of helicopter inflated head and body restraint systems, external fuel systems, and F-111 crew capsule are planned for the Impact Dynamics Research Facility. Figure 36 lists the areas of continuing research activities in landing dynamics and impact dynamics research for F. Y. 1994.

Spacecraft Dynamics Branch

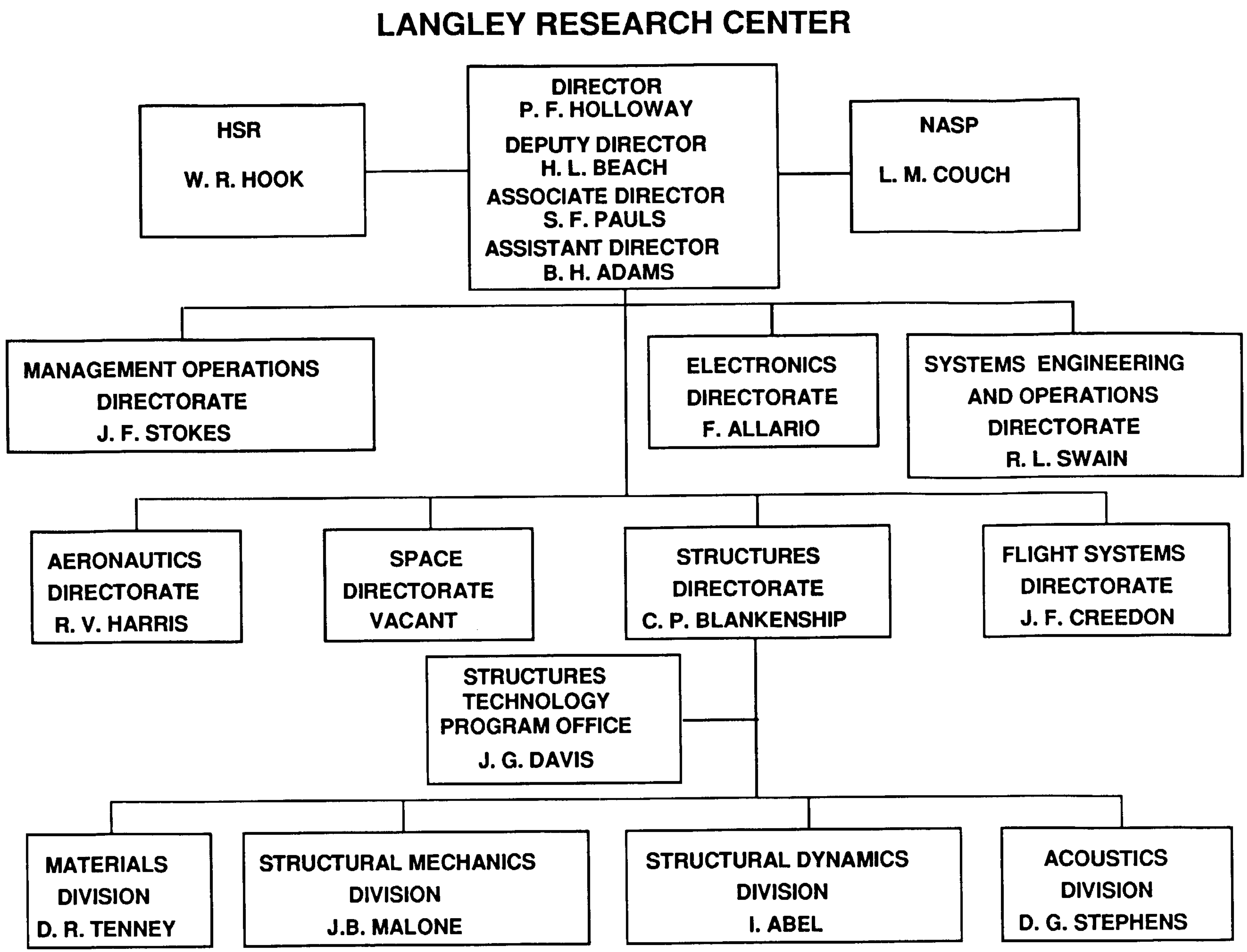
(Page 86)

For F. Y. 1994, the Spacecraft Dynamics Branch will develop structural dynamics and controls related technology for earth observation and planetary spacecraft. Emphasis will be on an instrument-pointing-jitter risk reduction experiment set for EOS AM-1 and collaborating Controls-Structures Integration (CSI) laboratory experiments. The primary effort, in conjunction with the EOS Project Office at the Goddard Space Flight Center and the EOS AM-1 prime contractor, will provide the flight controller with options to increase the jitter suppression capability of the spacecraft using ground-verified technologies which extend standard flight practice. Key among the experiment objectives is the definition of a flight measurements system to obtain data for identifying mathematical models of the actual on-orbit spacecraft dynamics. The identified models can then be used to update control laws as needed for performance improvement. In a related task, EOS AM-1 software augmentation by a back-up system to enable implementing multivariable control techniques in state-space form will also be investigated, and advanced stochastic control laws will be developed for possible flight evaluation, if feasible. The CSI Phase-3 Evolutionary Model will be installed in the Space Structures Research Laboratory and used to validate controls-structure integration methods addressing multi-sensor pointing issues. The Phase-3 Model will be a reconfiguration of existing structural hardware to simulate principal dynamic characteristics of the EOS AM-1 Spacecraft augmented by pointing gimbals and optical scoring system for science instrument pointing emulation.

Other planned spacecraft structural dynamics technology activities for F. Y. 1994 include participation in a multi-disciplinary integrated structures design trade study for the miniaturization of spacecraft launch mass and volume. Public release is planned for the previously developed System Observer Controller Identification Toolbox (SOCIT). The software, for the identification of mathematical models from measured dynamic data, is configured as a MATLAB toolbox and operates on desktop computers. A new large motion suspension device which allows limited three-dimensional motion of test articles in dynamic ground tests will be evaluated in the laboratory. An earth-based version of a variable geometry space truss is planned as a joint activity with DOE. The earth-based version is targeted for nuclear waste clean-up.

CONCLUDING REMARKS

This publication documents the F. Y. 1993 accomplishments, research, and technology highlights and F. Y. 1994 plans for the Structural Dynamics Division.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D. R. TENNEY
STRUCTURAL MECHANICS
DIVISION
J.B. MALONE
STRUCTURAL DYNAMICS
DIVISION
I. ABEL
ACOUSTICS
DIVISION
D. G. STEPHENS

Figure 1.

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J. Sobieski, Chief Scientist
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T. Johnson, Sec
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A/C Aeroelasticity
R/C Aeroelasticity
Benchmark Models
Advanced Concepts
Facilities

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Aeroservoelastic Analysis
CFD Methods Development

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Facilities

LANDING AND IMPACT DYNAMICS BRANCH
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F. Guthrie, Sec
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Tire Modeling
Crash Dynamics
Facilities

Figure 2.

STRUCTURAL DYNAMICS DIVISION

AERONAUTICS

- TRANSPORT AIRCRAFT
  - AEROELASTICITY
  - LANDING AND IMPACT DYNAMICS
- HIGH PERFORMANCE AIRCRAFT
  - AEROELASTICITY
- ROTORCRAFT
  - AEROELASTICITY
- ANALYTICAL METHODS

SPACE

- LARGE SPACE STRUCTURES
  - STRUCTURAL DYNAMICS
  - CONTROL STRUCTURES INTERACTION

Figure 3.

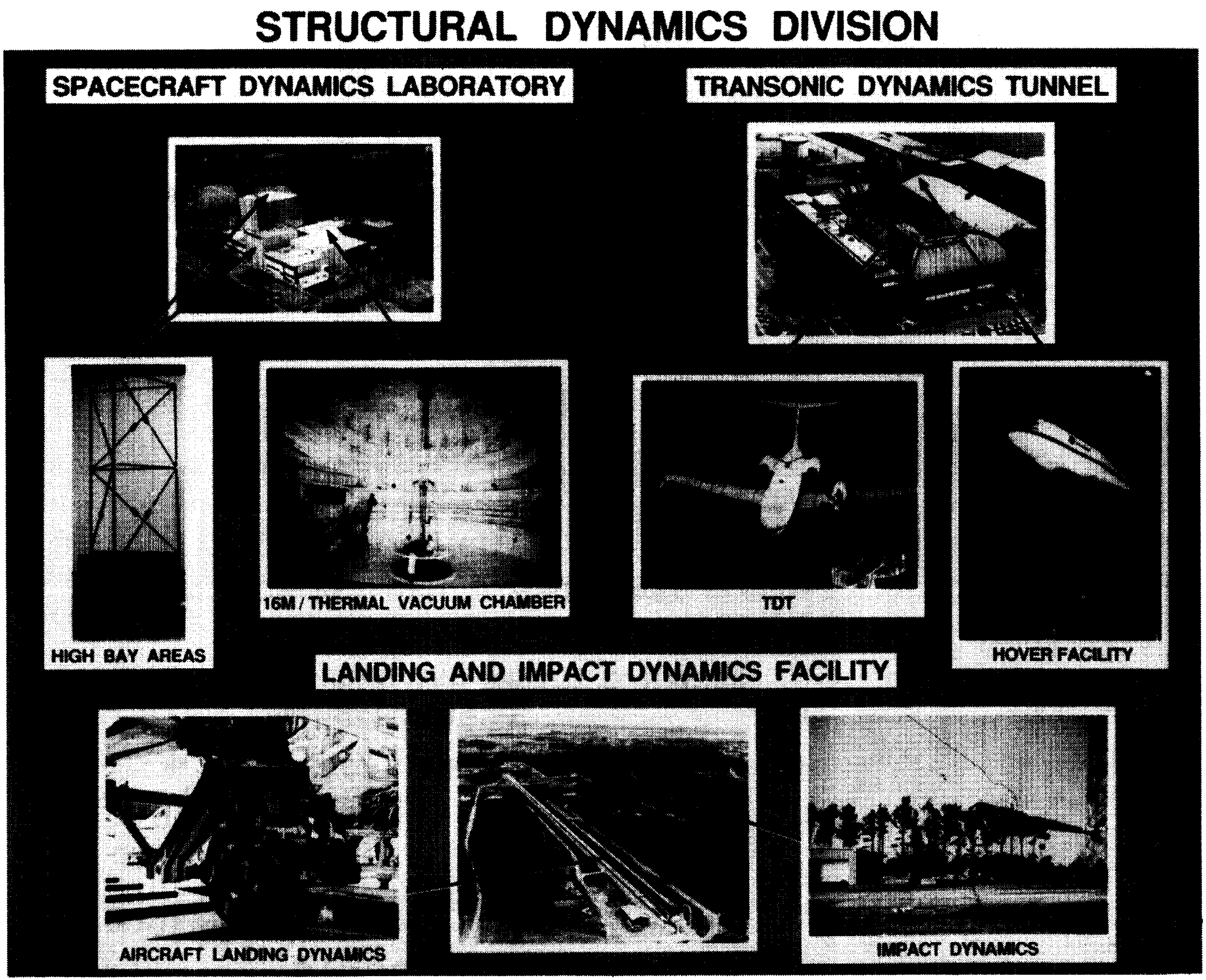
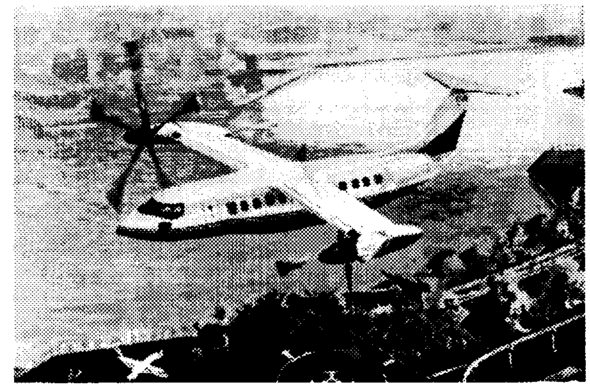

STRUCTURAL DYNAMICS DIVISION
SPACECRAFT DYNAMICS LABORATORY
TRANSONIC DYNAMICS TUNNEL
HIGH BAY AREAS
16M / THERMAL VACUUM CHAMBER
TDT
HOVER FACILITY
LANDING AND IMPACT DYNAMICS FACILITY
AIRCRAFT LANDING DYNAMICS
IMPACT DYNAMICS

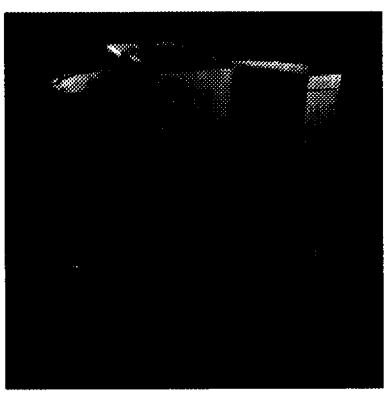
Figure 4.

Aeroelastic Analysis and Optimization Branch

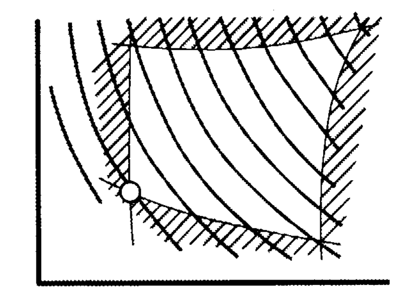
Aircraft



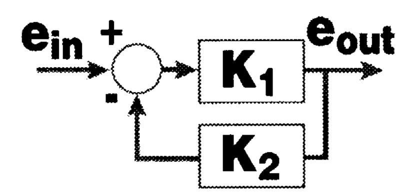
Rotorcraft



Computational methods



Optimization



Control laws

Figure 5.

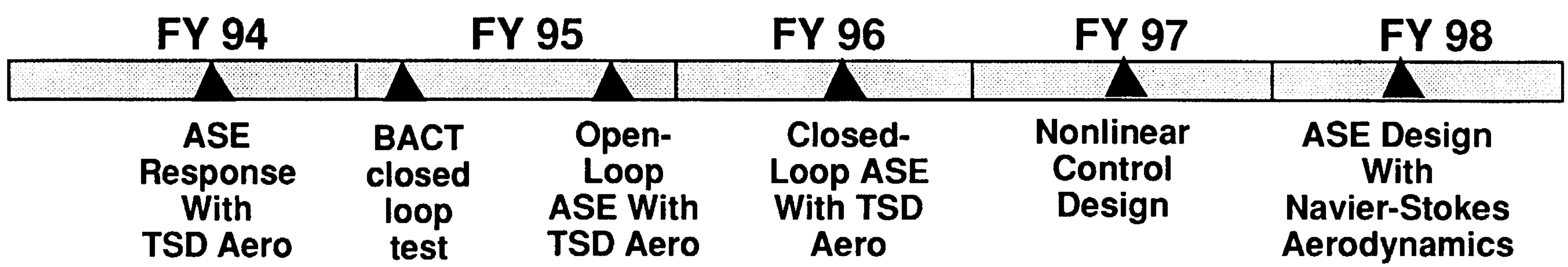
AEROELASTIC ANALYSIS AND OPTIMIZATION BRANCH PLANS (FY 94-98)

GOAL

DEVELOP VALIDATED METHODS FOR AEROSERVOELASTIC ANALYSIS AND DESIGN

KEY OBJECTIVES

- AEROSERVOELASTICITY



- COMPUTATIONAL METHODS FOR AIRCRAFT AEROELASTIC ANALYSIS

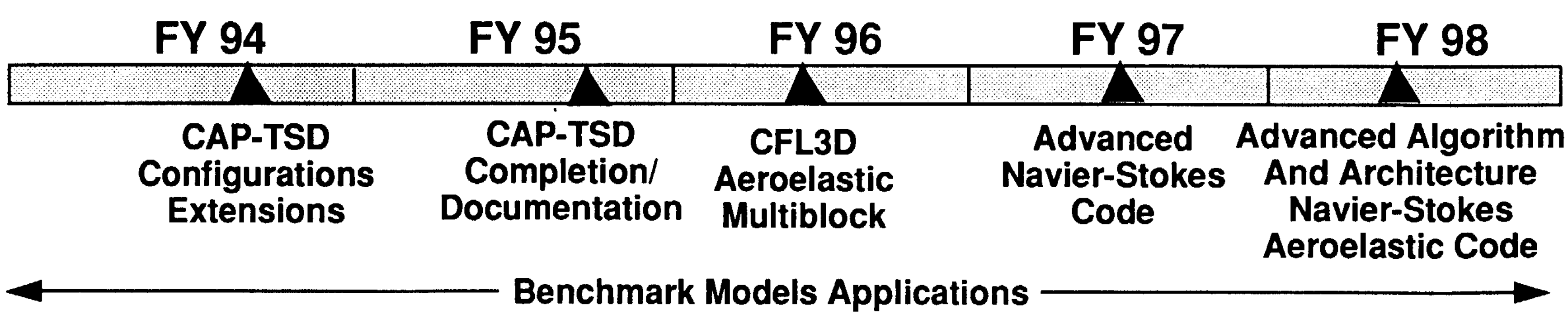


Figure 6 (a).

AEROELASTIC ANALYSIS AND OPTIMIZATION BRANCH PLANS (FY 94-98)

GOAL

DEVELOP COMPREHENSIVE METHODOLOGY FOR OPTIMAL MULTI-DISCIPLINARY DESIGN

KEY OBJECTIVES

- METHODOLOGY

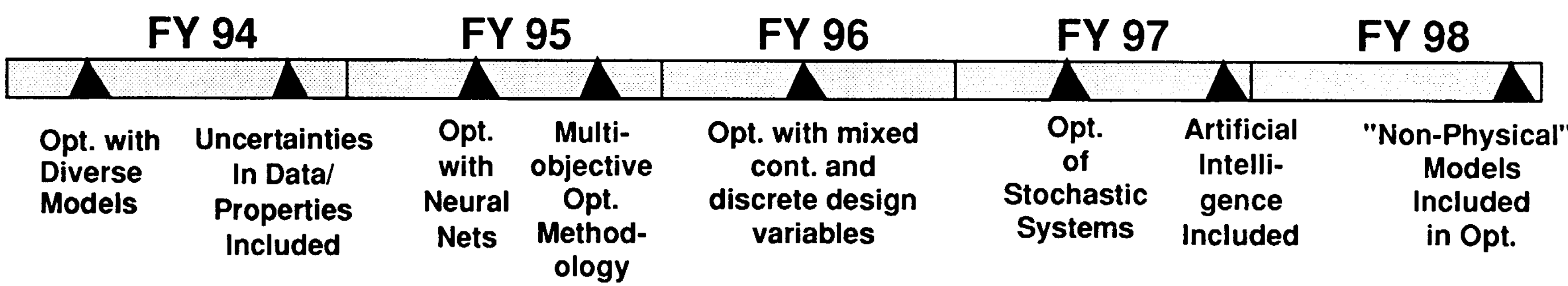


Figure 6 (b).

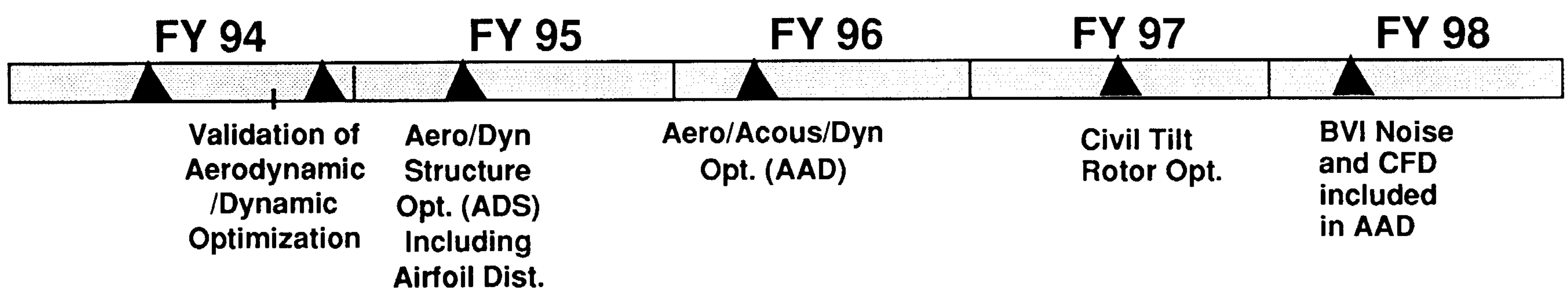
AEROELASTIC ANALYSIS AND OPTIMIZATION BRANCH PLANS (FY 94-98)

GOAL

DEMONSTRATE OPTIMAL DESIGN

KEY OBJECTIVES

- ROTORCRAFT



- HIGH SPEED CIVIL TRANSPORT

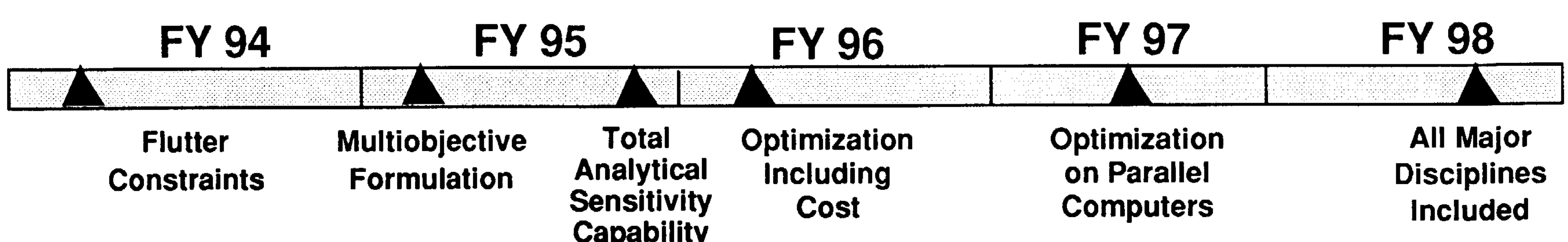


Figure 6 (c).

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LOW-SPEED TURBULENCE MEASUREMENTS OF AIR FLOW IN THE TRANSONIC DYNAMICS TUNNEL

Robert K. Sleeper
Aeroelastic Analysis and Optimization Branch

Boyd Perry III
Aeroelasticity Branch

RTOP 505-63-50

Research Objective: The Langley Transonic Dynamics Tunnel (TDT) conducts forced response studies and studies of aircraft equipped with active controls. For such studies, knowledge of the turbulence in the test section is an important consideration. The objective of this research is to measure the vertical and lateral velocity components of turbulence in the TDT.

Approach: A constant-temperature anemometer equipped with a hot-film X-probe was employed to measure the tunnel turbulence components in air at the center of the test section for Mach numbers below 0.3 at an atmospheric stagnation pressure. Velocity component time histories were generated. Standard deviations of the time histories were computed. Tunnel turbulence is expressed in terms of the standard deviation and its percentage of the tunnel velocity, a parameter that has been denoted as turbulence, in the accompanying of figure. The vertical and lateral turbulence components are distinguished in the figure, but since they had similar magnitudes, they are treated together as a function of tunnel velocity at the left of the figure and as a function of dynamic pressure at the right of the figure. The upper part of figure depicts the standard deviation, and the lower part shows the turbulence parameter. Linear least square estimates with their corresponding r-values, where the r-value is the square root of the coefficient of determination, also are included. An r-value of unity denotes perfect correlation.

Accomplishment Description: As expected, the turbulence as indicated by the standard deviation increased with tunnel velocity and dynamic pressure, reaching values as high as 3.5 feet per second (fps) at a tunnel velocity of 450 fps. The turbulence parameter ranged from 0.19 percent to 0.77 percent and appeared to increase slightly with the tunnel velocity and the dynamic pressure.

Significance: The results indicate that for air flow below Mach 0.3 at atmospheric pressure, the vertical and lateral turbulence components have similar magnitudes and the turbulence parameter did not exceed 0.8 percent.

Plans: Further turbulence measurements at higher Mach numbers and at atmospheric and reduced stagnation pressures, both in air and heavy gas, are planned.

Figure 7 (a).

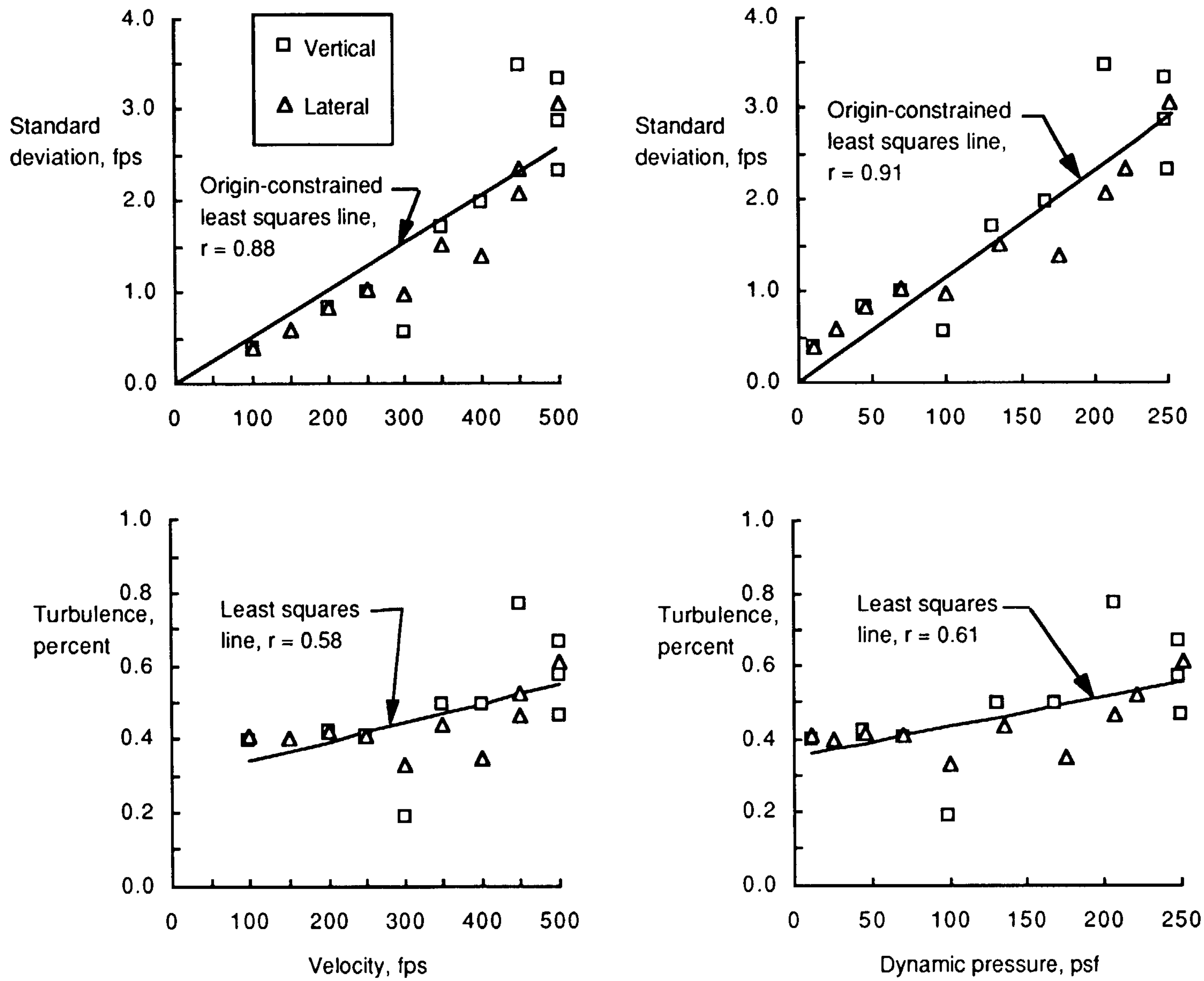

Vertical
Lateral
Standard deviation, fps
Origin-constrained least squares line, r = 0.88
Origin-constrained least squares line, r = 0.91
Turbulence, percent
Least squares line, r = 0.58
Least squares line, r = 0.61
Velocity, fps
Dynamic pressure, psf

Figure 7 (b).

TRANSONIC SHOCK OSCILLATION ONSET PHENOMENA DEMONSTRATED COMPUTATIONALLY

John W. Edwards
Aeroelastic Analysis and Optimization Branch

RTOP 505-63-50

Research Objective: The objective of this research is to develop a robust and efficient computational method for computing transonic flows that involve the onset of separation and flows that are naturally unsteady and involve oscillations of the shock/boundary layer system with a characteristic frequency.

Approach: At high subsonic Mach numbers, a region of supersonic flow terminated by a shock wave develops over the airfoil. The viscous boundary layer next to the airfoil grows rapidly underneath the shock and aft on the airfoil, eventually leading to flow separation. Depending upon the airfoil section, separation may initiate at the trailing-edge or at the foot of the shock, where a closed separation bubble may be seen. To simulate such flows, the inviscid CAP-TSD (Computational Aeroelasticity Program-Transonic Small Disturbance) code has been coupled with an inverse, integral boundary layer model (CAP-TSDV code).

Accomplishment Description: Calculations of attached and separated flow conditions have been made with the CAP-TSDV code for the NACA 0012 and 18 percent thick circular arc airfoils. The upper left of the figure shows excellent agreement with the experimental buffet onset boundary for the NACA 0012 airfoil at a Reynolds number of 10 million. The results are an improvement over those of ONERA researchers who used a similar potential code but a different boundary layer coupling method. Detailed study of the buffet onset at $M = 0.775$ revealed the amplitude bifurcation shown in the bottom left of the figure. The circular arc airfoil exhibits a different shock oscillation onset boundary; for increasing Mach number, oscillations occur for $0.76 < M < 0.78$ while for decreasing Mach number, oscillations persist to $M = 0.73$. Within this "hysteresis" region of $0.73 < M < 0.76$, calculations with the CAP-TSDV code have revealed the "jump" stability phenomena illustrated in the lower right figure.

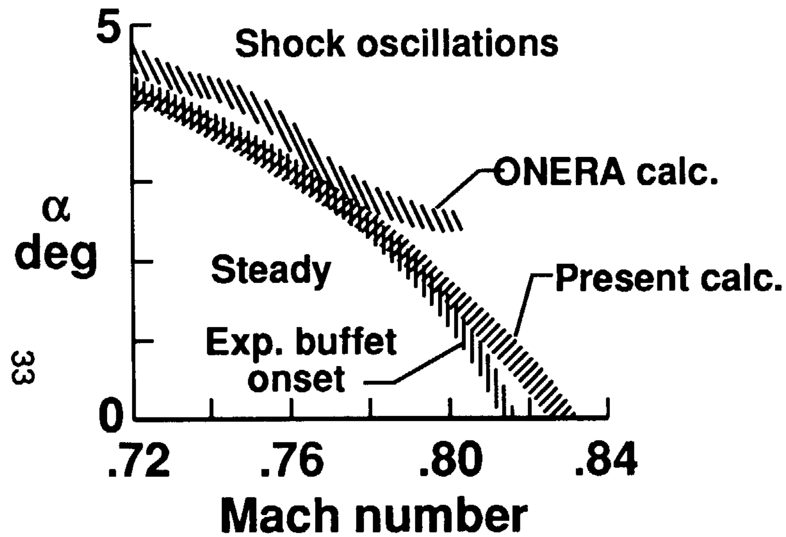
Significance: Investigation of boundary layer parameters just below the oscillation onset conditions for the two airfoils revealed that there is a shock-induced separation bubble on the NACA 0012 airfoil (with downstream reattached flow) whereas the circular arc airfoil experienced trailing-edge separation (within the Mach number hysteresis region). Further increases in either Mach number or angle of attack trigger the oscillations when a) flow at the trailing-edge begins to separate (NACA 0012 airfoil) or b) the shock strengthens sufficiently to induce a separation bubble (circular arc airfoil). The jump phenomena shown for the latter airfoil can thus occur when sufficiently large perturbations are applied.

Plans: The CAP-TSDV code will be used for flutter calculations of wings at transonic speeds in order to determine the effects of viscosity. The ability to treat separating and reattaching flows will enable treatment of nonclassical aeroelastic features such as control surface buzz and limit cycle oscillations.

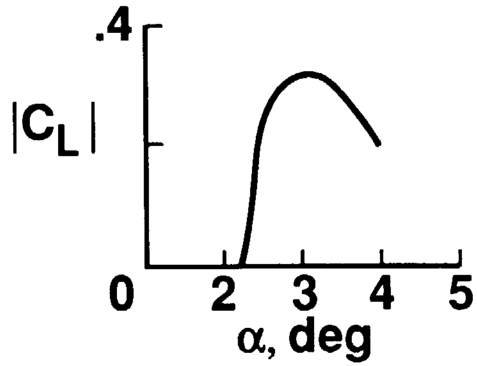
Figure 8 (a).

TWO TRANSONIC SHOCK OSCILLATION ONSET PHENOMENA DEMONSTRATED COMPUTATIONALLY

- Shock-induced separation onset shows bifurcation phenomena
  NACA 0012 airfoil, $Re_c = 10^7$
  - Buffet onset boundary



- Amplitude bifurcation, M = 0.775



- CAP-TSDV potential code with interactive viscous boundary layer model
- Transonic shock-induced oscillations calculated for two airfoils
- Mach number ranges and oscillation frequencies agree with experiment

- Trailing-edge separation onset shows "jump" stability phenomena
  18% circular arc airfoil, M = 0.74, $Re_c = 10^7$

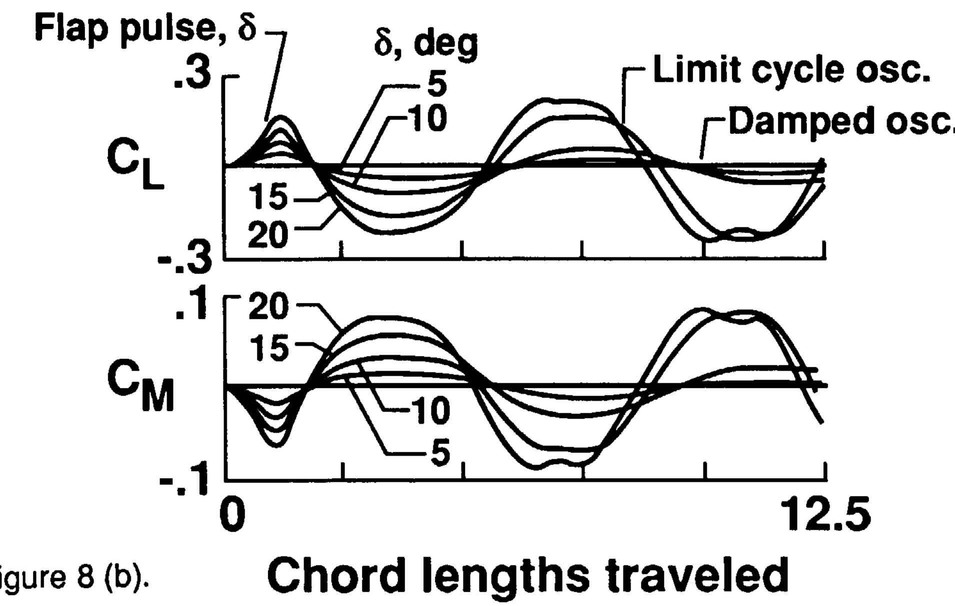


Figure 8 (b).

ROBUSTNESS ANALYSIS METHODOLOGY FOR A MULTIRATE FLUTTER SUPPRESSION SYSTEM DEVELOPED

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University of Washington

RTOP 505-63-50

Research Objectives: The objectives of this research are to develop a methodology for analyzing multirate digital control systems for robustness and to use the methodology to evaluate the multirate flutter suppression control laws for the Benchmark Active Controls Testing (BACT) Model Wing.

Approach: A unified approach for analyzing the robustness and performance of multirate systems was developed. The approach is a combination of existing multirate performance and robustness analysis tools and some new developments to relate them to a single-rate equivalent system, in a consistent state-space formulation. The multirate system is modeled as periodically time-varying system followed by transformation into an equivalent single-rate system (ESRS). This transformation allows one to combine the ESRS with the rest of the model in series, parallel or in feedback. It can be shown that the multirate system is stable whenever its ESRS is stable. Thus the robustness of the multirate system can be determined by applying structured and unstructured singular value analysis to that system's ESRS.

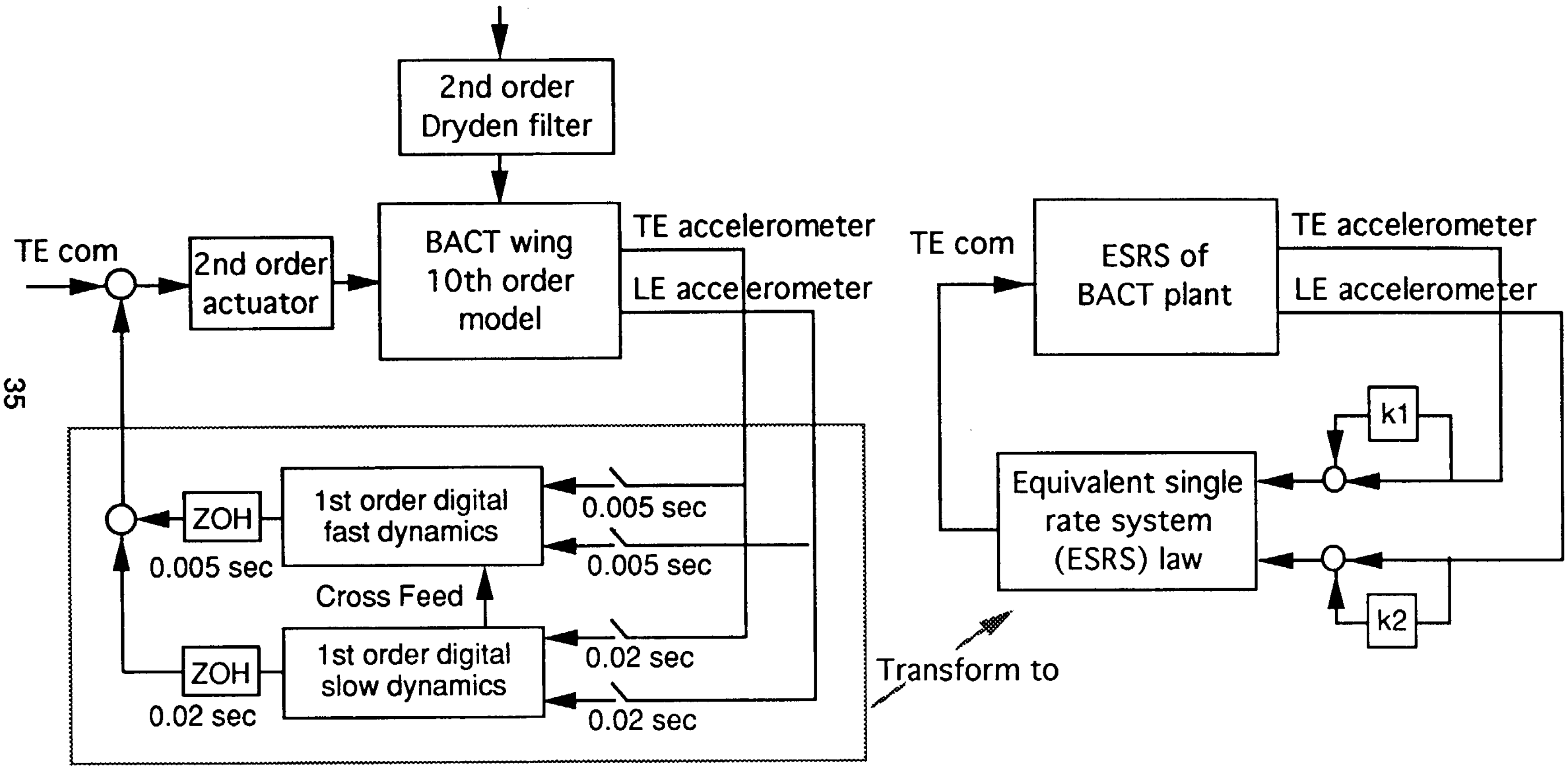
Accomplishment Description: Convenient mathematical connection between the input/output vectors of a multirate system and its equivalent ESRS signal was established. The corresponding two-norms and root-mean-square (RMS) values were shown to be equal. The maximum RMS gain of the multirate system is the H-infinity norm of its ESRS transfer function. The relation between a single-rate transfer function and its ESRS transfer function also was determined. The method was applied to evaluate the robustness of the multirate flutter suppression system for the NACA 0012 BACT model as shown at the left of the figure. The robustness to structured and unstructured perturbation for the two-parameter (k1 and k2) ESRS system shown at the right of the figure was evaluated.

Significance: Robustness and performance of any multirate design can be analyzed by transforming the closed-loop multirate system into equivalent single-rate systems and applying modified linear time-invariant techniques, such as multi-loop Nyquist Criteria, unstructured singular value analysis and structured singular value or μ analysis.

Plans: These control laws will be verified using experimentally determined BACT plant model and tested in the SDyD Transonic Dynamics Tunnel. A user manual for the multirate design and optimization toolbox will be developed.

Figure 9 (a).

ROBUSTNESS ANALYSIS METHODOLOGY FOR A MULTIRATE FLUTTER SUPPRESSION SYSTEM DEVELOPED



Multirate flutter suppression system

Two parameter ESRS system for robustness analysis

Figure 9 (b).

COUPLING OF STRUCTURES TO AERODYNAMIC/DYNAMIC OPTIMIZATION ASSURES VIABILITY OF ROTOR BLADES

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RTOP 505-36-06

Research Objective: The objective of this research is to develop a rotor blade optimization procedure that leads to designs in which horsepower required is minimized, undesirable dynamic response is minimized, and structural integrity is assured. At the same time, the procedure should determine if the required blade stiffness distributions are attainable.

Approach: The optimization procedure is based on the theory of multilevel decomposition illustrated at the left in the figure. The upper level performs an integrated aerodynamic/dynamic optimization that minimizes an objective function which is a linear combination of vibratory load and the horsepowers required in hover, in forward flight, and in maneuver. The design variables in the upper level include blade planform; pretwist; stiffness distributions; and tuning masses and locations. The lower level sizes the internal structure of a wing box to satisfy strength constraints and minimizes an objective function which is a measure of the difference between the stiffnesses required at the upper level and the stiffnesses attainable from the wing box sizing. It is necessary to iterate between the upper and lower levels because, in general, it is not possible to size a wing box to obtain an arbitrary set of four stiffnesses (bending in two directions, torsion, and extension). The design iterations represent a dialogue between the levels that upon convergence establish compatible upper-level and lower-level designs.

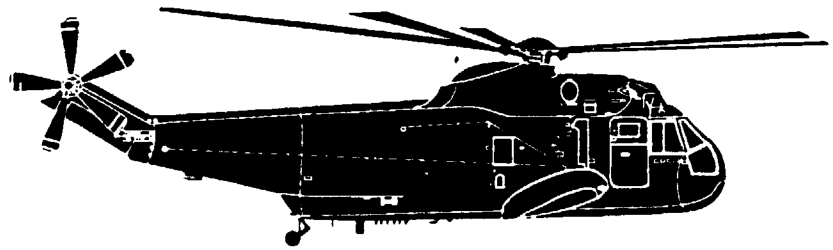
Accomplishment Description: The procedure has been demonstrated successfully in the design of a rotor blade. Some illustrative results are shown in the figure. These results illustrate the importance of using multilevel optimization to couple the structural design with the aerodynamic/dynamic optimization. Uncoupled means there is no structural dialogue and coupled means there is structural dialogue. As shown at the upper right, the uncoupled result in which the structural optimization follows the completed aerodynamic/dynamic optimization is unable to match the required upper-level stiffnesses but is able to satisfy strength requirements. In the coupled result, shown in the lower right, the required and attainable stiffness distributions are nearly identical. The consistency was brought about by the iterative dialogue inherent in the current multilevel approach. The upper level optimization is able to improve aerodynamic and dynamic measures since there is a decrease in all the horsepowers required and vibratory load.

Significance: The present procedure provides an optimization technique that is compatible with industrial design practices in which the aerodynamic and dynamic design is performed at a global level and the structural design is carried out at a detailed level with considerable dialogue and compromise among the groups. This is the first example of the use of multilevel decomposition applied to rotor blade multidisciplinary design optimization process.

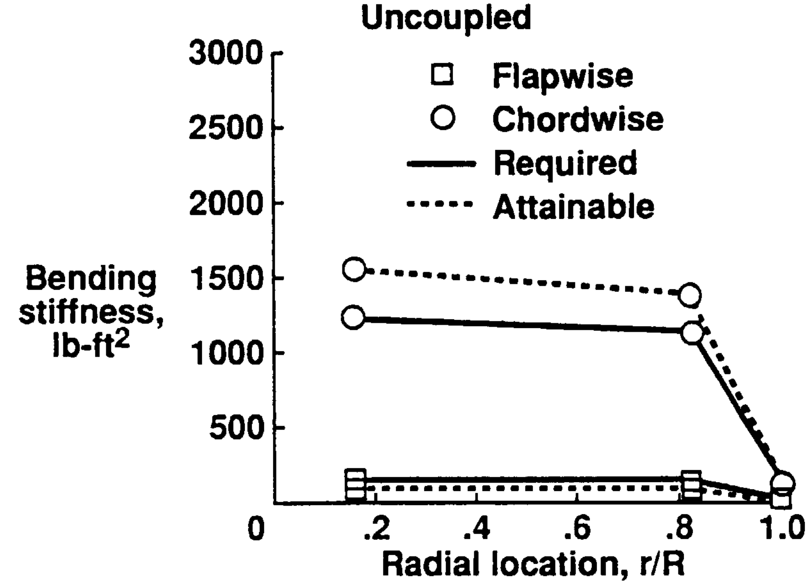
Future Plans: The procedure is in the process of being extended to include blade weight and acoustics requirements after which it will be made available to influence the optimization of a low noise rotor as part of the SH(CT) program.

Figure 10 (a).

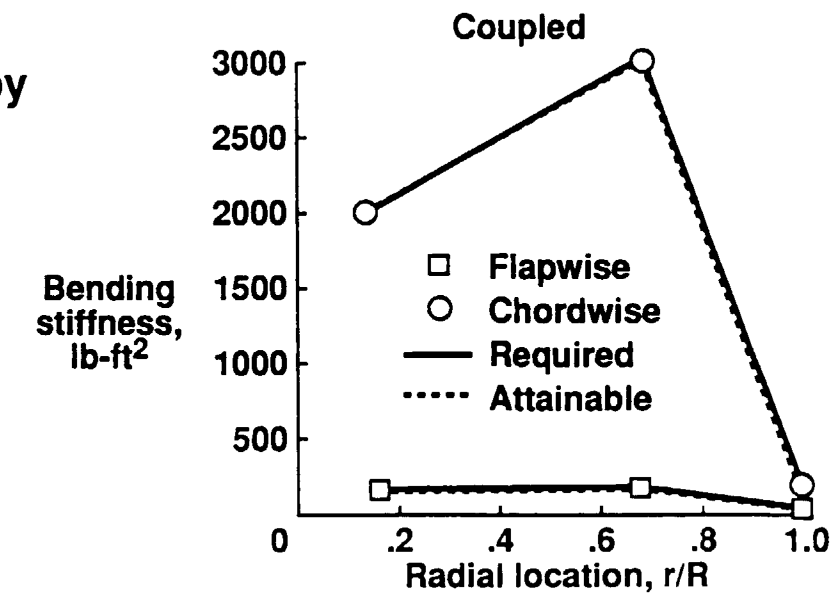
COUPLING OF STRUCTURES TO AERODYAMIC/DYNAMIC OPTIMIZATION ASSURES VIABILITY OF ROTOR BLADES

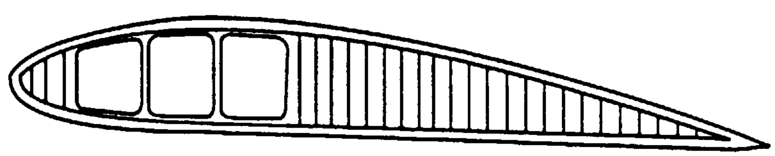


Upper level: optimize performance and dynamics



Compromise between stiffnesses required by upper level and attainable in lower level





Lower level: design internal structure

Figure 10 (b).

MULTIDISCIPLINARY DESIGN OPTIMIZATION IMPROVES PERFORMANCE FOR HSCT STUDY CONFIGURATION

Jaroslaw Sobieski
Structural Dynamics Division

Eric R. Unger
NRC, Aeroelastic Analysis and Optimization Branch

Peter G. Coen
Vehicle Integration Branch

RTOP 505-63-50

Research Objective: The objective of this research is to develop an integrated aerodynamic and performance optimization system to design a conceptual High-Speed Civil Transport wing.

Approach: For the design study an optimizer is coupled to the analysis system that consists of linear-theory aerodynamics, parametric weight analysis, and a complete mission evaluation using the rigid-wing drag polars. The optimization proceeds as a sequence of approximate problems where costly constraints and objectives are linearized with respect to the parametric description of the design problem. Since simple linearizations are generally valid only near the point at which they are calculated, limits are placed on the changes that can be made to the design parameters during a cycle. The optimal changes to these design parameters are found using the OPTDES optimization code with linear programming. The result of this operation is an approximate optimum design, at which point the constraints and objective are relinearized, and the process is repeated until convergence.

Accomplishment Description: An integrated aerodynamic and performance design system was developed. This system was applied to a supersonic transport wing planform where shape was optimized for either a maximum range objective or a minimum weight objective. Initial and final planforms are shown in the figure at the lower left. For both cases, the initial planform was defined by NASA Langley's 2.4e configuration, which represents a final conceptual design that was obtained using traditional design techniques. In the range maximization problem, the aircraft range was increased by 6.4 percent with a negligible change in take-off gross weight (see the figure in the lower right). For the weight minimization problem, take-off gross weight was decreased by 8.1 percent with a negligible change in aircraft range.

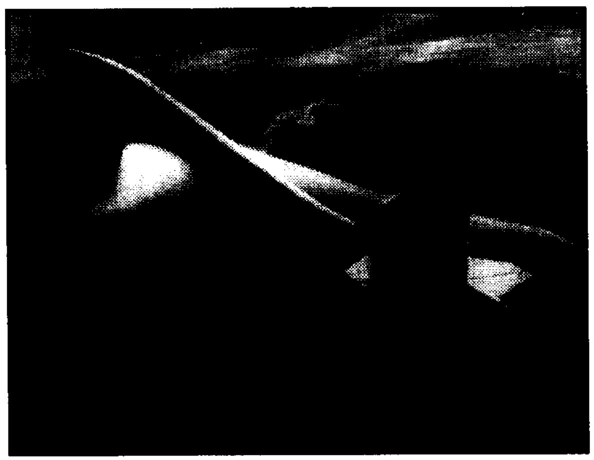
Significance: The integrated design system demonstrated that subtle changes in planform have a significant impact on the aircraft's performance. Furthermore, developing the baseline aircraft design required weeks of effort while this new study required only 40 hours of clock time on a workstation to design a planform for a given objective and constraint set. Objective functions and constraints can be easily modified to study the impact of changing the design requirements on a final product without resorting to costly trial-and-error fixes frequently resorted to in traditional design procedures.

Plans: This work represents an initial study of integrated aerodynamic-performance design to a conceptual supersonic transport. Including the effects of fully integrated structural and flutter analysis is currently under development. Longer range goals include the incorporation of non-linear aerodynamics methods, and possibly, multi-objective range and weight optimizations.

Figure 11 (a).

Multidisciplinary Design Optimization Improves Performance for HSCT Study Configuration

High Speed Civil Transport



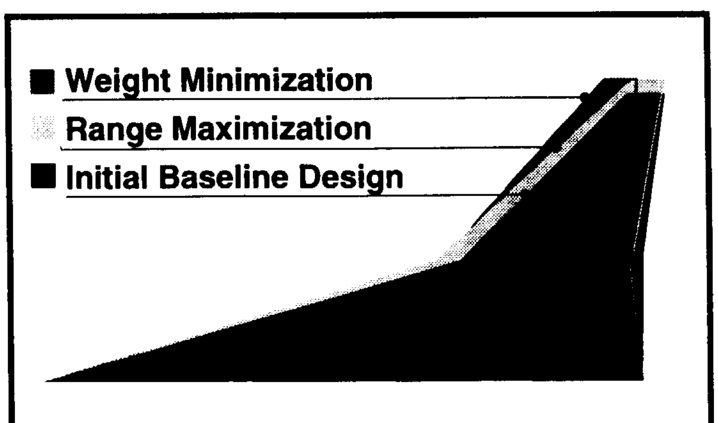
Accomplishments

Method implemented to optimize planform, thickness, and camber for performance

Significance

The results of application showed that even subtle changes can have a significant impact on performance

Wing Planforms



Range And Weight Optimizations

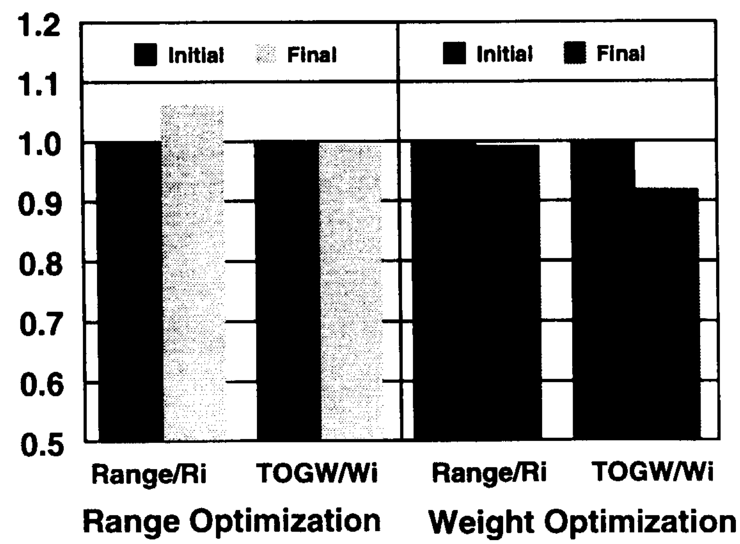


Figure 11 (b).

DISSEMINATION AND APPLICATIONS OF THE DESIGN MANAGER'S AID FOR INTELLIGENT DECOMPOSITION (DeMAID)

James L. Rogers
Aeroelastic Analysis and Optimization Branch

RTOP 505-63-50-06

Research Objective: Many engineering systems are large and multidisciplinary. Before the design of such complex systems can begin, much time and money are invested in determining the possible interactions among the participating processes. The ordering and decomposition of the processes must be repeated as new information becomes available or as the design specifications change. Determining this ordering is not easy, and often important interactions are overlooked. The purpose of this research is to develop a software tool to aid the designer in making early design decisions and produce a more optimal design at less cost in less time.

Approach: The Design Manager's Aid for Intelligent Decomposition (DeMAID) was developed as an aid to the design manager in decomposing large, complex, multidisciplinary processes. DeMAID orders the design processes, groups iterative processes, and displays them in a matrix format. From this display, the design manager can see the interactions among the processes, reorder the processes as needed, decompose the problem into a hierarchy of subsystems, and determine which processes can be performed in parallel.

Accomplishment Description: Since the first release of DeMAID in 1989, the number of users has grown to thirteen. The industries include Northrop, McDonnell Douglas, Rockwell, Concurrent Engineering Research Center, Boeing, Digital Equipment Corporation (DEC), General Electric, Lockheed Ft. Worth, and Lockheed Georgia. Universities include MIT, Georgia Tech, SUNY Buffalo, and Stanford. Applications include the Single Stage to Orbit project at McDonnell Douglas, being contemplated for use with the large airplane project at Boeing, time-to-market for various computer systems at DEC, an automobile brake design project at MIT, and the incorporation of DeMAID into a graduate design course at Georgia Tech.

Significance: DeMAID is proving to be a very flexible software tool. It is being applied to a wide variety of projects. With DeMAID, design managers can quickly examine different sequences for ordering the design modules, reduce iterative processes, and examine possible conflicts.

Plans: Based on feedback and surveys from DeMAID users, enhancements are being made to the software to meet their needs. Some of these enhancements include determining the strengths of the interfaces, more detailed tracing of output, user-friendly aids such as pull-down menus, and optimizing the sequence of modules within an iterative process.

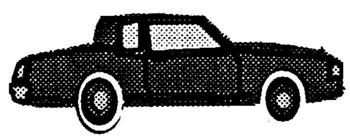
Figure 12 (a).

DISSEMINATION AND APPLICATIONS OF DeMAID

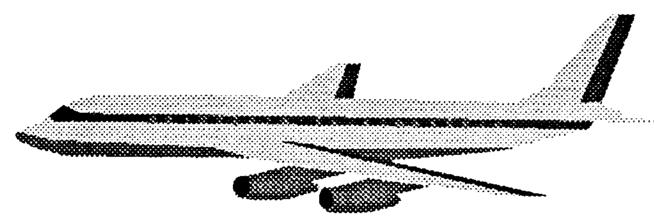
<u>Universities</u>
MIT
Georgia Tech
SUNY Buffalo
Stanford
CERC

<u>Aerospace Industry</u>
Boeing
Lockheed Georgia
Lockheed Ft. Worth
Northrop
McDonnell Douglas
Rockwell

<u>Other Industry</u>
Digital Equipment Corp.
General Electric Corp.

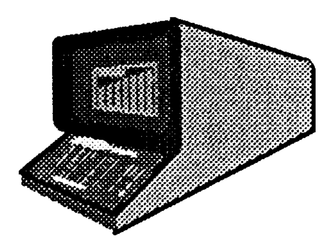


Brake Design (MIT)



Large Airplane Project (Boeing)

Single Stage to Orbit
(McDonnell Douglas)



Time-to-Market for Computers
(DEC)

Figure 12 (b).

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AEROELASTICITY BRANCH
Aircraft Aeroelasticity
Rotorcraft Aeroelasticity
Transonic Dynamics Tunnel
Benchmark Models
Advanced Concepts
Buffet alleviation
Panel flutter suppression
Flutter suppression
Aerodynamic shape control

Figure 13.

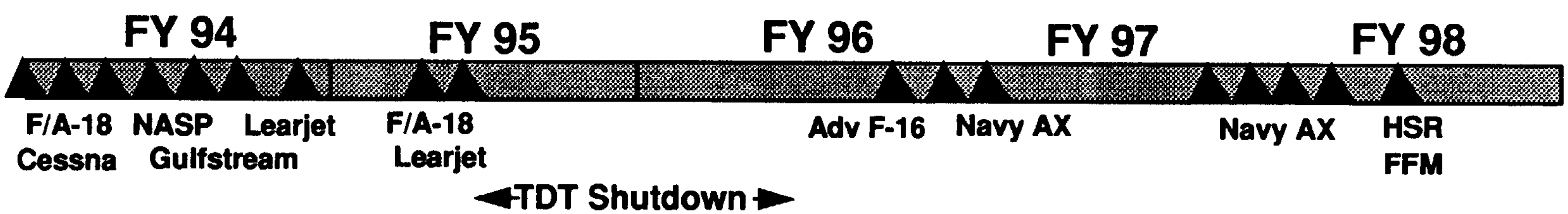
AEROELASTICITY BRANCH
FUTURE PLANS (FY 94-98)

GOAL

PREDICTION AND CONTROL OF AEROELASTIC RESPONSE

KEY OBJECTIVES

- VERIFY THAT NEW NASA/DOD/INDUSTRY FLIGHT VEHICLES HAVE ADEQUATE AEROELASTIC PROPERTIES



- MEASURE BENCHMARK AERODYNAMIC AND AEROELASTIC DATA

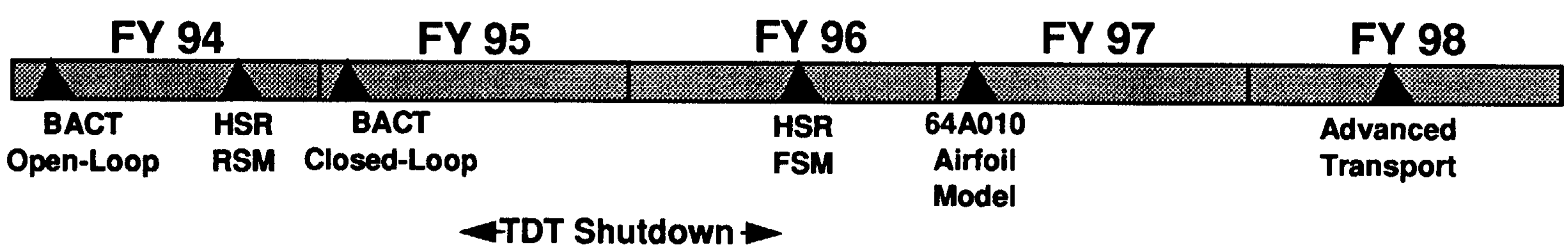


Figure 14 (a).

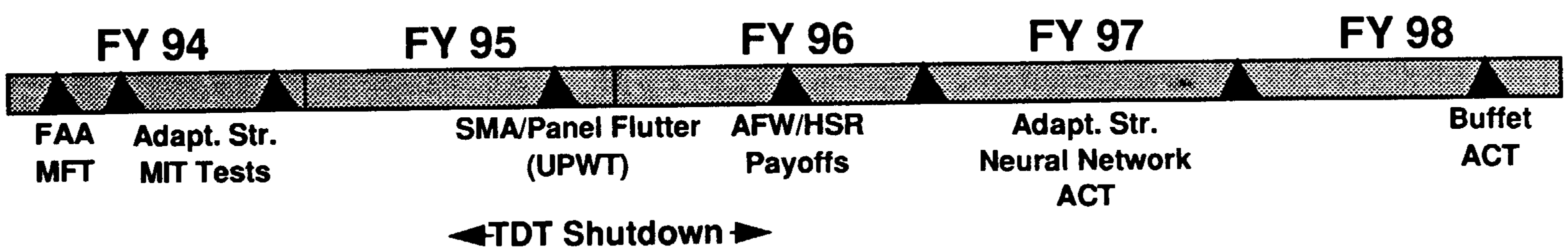
AEROELASTICITY BRANCH
FUTURE PLANS (FY 94-98)

GOAL

PREDICTION AND CONTROL OF AEROELASTIC RESPONSE

KEY OBJECTIVES

- DEVELOP ADVANCED CONCEPTS FOR EXPLOITING AEROELASTIC RESPONSE



- UNDERSTAND STRUCTURAL DYNAMIC AND AEROELASTIC CHARACTERISTICS OF ADVANCED ROTORCRAFT

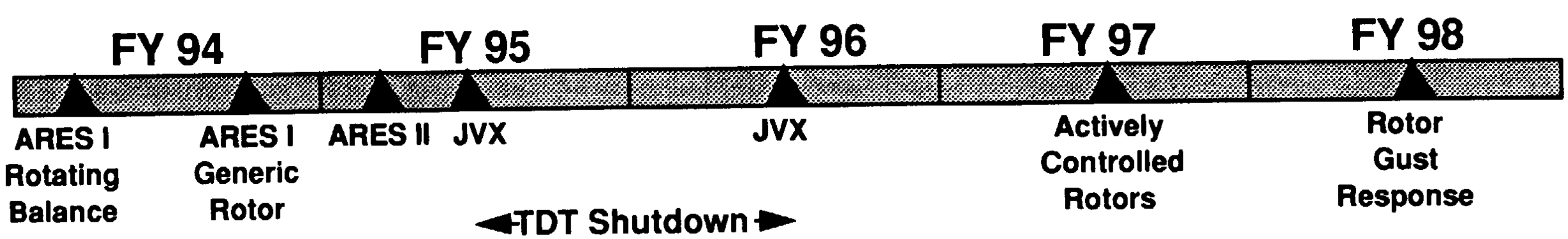


Figure 14 (b).

TRANSONIC AEROELASTIC CHARACTERISTICS DETERMINED FOR MODERN TRANSPORT DESIGN IN TDT

Donald F. Keller and Stanley R. Cole
Aeroelasticity Branch

RTOP 505-63-50

Research Objective: Modern transport aircraft operate near, and sometimes in, the transonic speed regime where the performance of the aircraft can be adversely affected by various aeroelastic phenomena such as flutter, limit cycle oscillations (LCO), and buffet. Flutter is a self-sustaining oscillation involving the coalescence of several elastic modes cf vibration; at conditions above the flutter speed highly-coupled oscillations occur and can, at times, result in catastrophic failure of the lifting surface. LCO, which are related to flutter, are self-sustaining, limited-amplitude, single-degree-of-freedom oscillations of a surface; LCO rarely result in structural failures. Transonic buffet is an irregular oscillation of a surface resulting from randomly varying flow conditions; the effects of buffet can result in structural fatigue problems. To investigate and understand the various aeroelastic phenomena associated with modern high-speed transports and to provide a database to evaluate linear state-of-the-art and CFD unsteady aerodynamic and aeroelasticity methods, a cooperative effort between NASA and the Boeing Commercial Airplane Group was established.

Approach: An aeroelastic model of a typical modern transport with a supercritical airfoil section was tested in the Transonic Dynamics Tunnel (TDT) at Mach numbers ranging from approximately 0.6 to 1.0 in a heavy gas test medium. A photograph of the model mounted in the tunnel test section is presented in the left part of the figure. The wing was instrumented to measure steady and unsteady pressures on the upper and lower surfaces at two span locations. A removable winglet was also available to provide wing tip shape effects data. A flow-through engine nacelle was mounted to the wing using either linear or nonlinear springs and the flow through the nacelle could be reduced using a choke plate. The wing was attached to a sidewall turntable through a 5-component force balance. A rigid fuselage half-body provided realistic flow over the wing and removed the wing from the wind-tunnel wall boundary layer. In addition, wing internal fuel was simulated and could be varied remotely.

Accomplishment Description: The aircraft parameters varied during the tests included fuel load, nacelle spring stiffness, nacelle flow blockage, winglet (on/off), and angle-of-attack. On the right side of the figure, experimental flutter points for one of the configurations tested are compared to Boeing flutter predictions based on a modified strip theory approach. In addition to obtaining actual flutter points, each configuration tested experienced high vibratory response in the wing first bending mode in a narrow portion of the transonic region. Maximum amplitudes of the motion, described by the test team as transonic buffeting and not LCO, occurred at a Mach number of about 0.94 and are indicated by the shaded area at the bottom of the plot. Significant flow separation along the trailing edge of the upper surface and along the mid-chord region of the lower surface of the wing was observed at M=0.94 using tufts mounted on the wing and nacelle.

Significance: This cooperative study provided important transonic aeroelastic data. The high dynamic wing response (transonic buffet) and the classical flutter data will be useful in evaluating linear and nonlinear CFD prediction codes used in the design and analysis of future transport aircraft.

Future Plans: Experimental and analytical results obtained from this study will be published as a joint NASA/Boeing formal report.

Figure 15 (a).

TRANSONIC AEROELASTIC CHARACTERISTICS DETERMINED FOR MODERN TRANSPORT DESIGN IN TDT

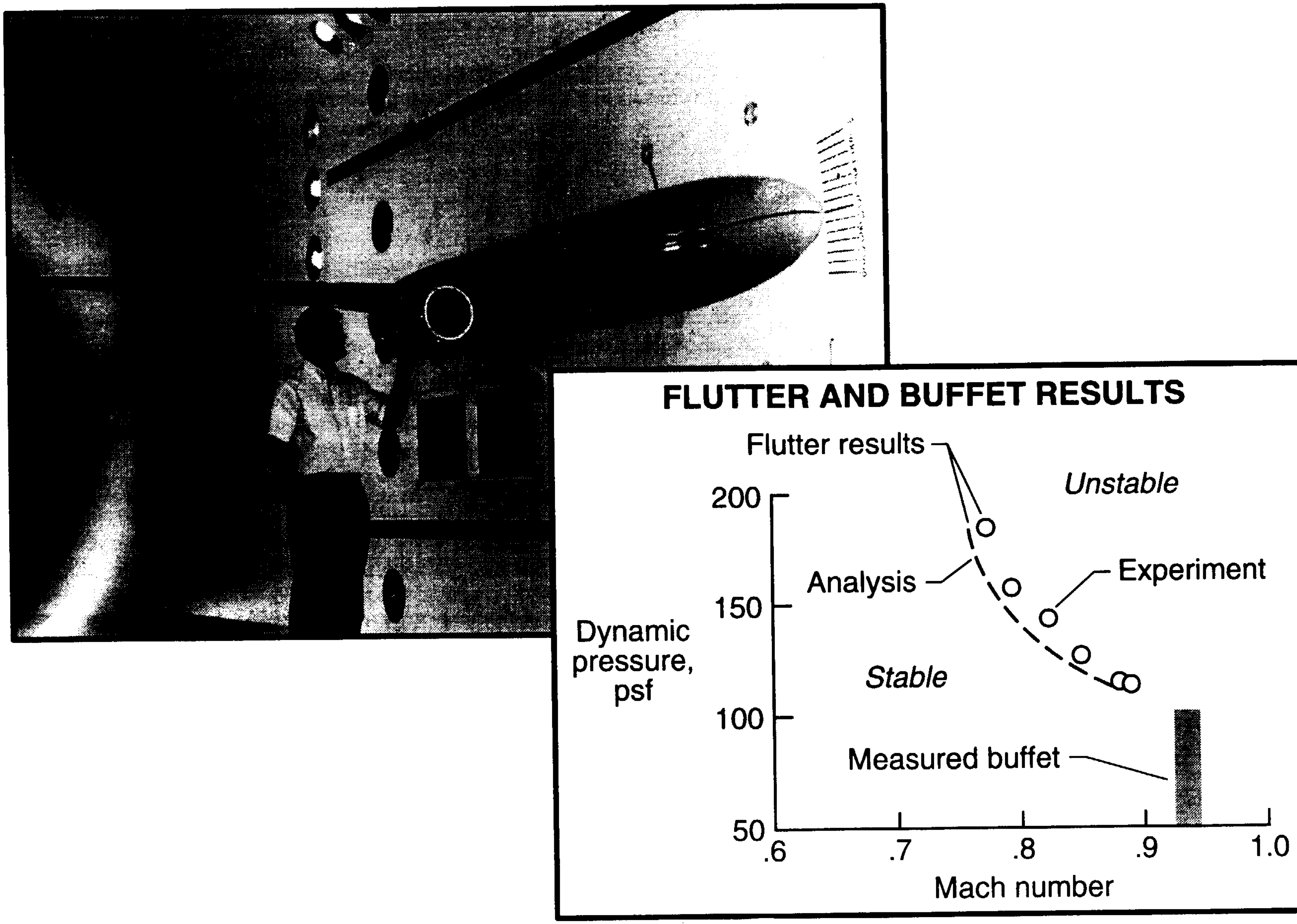


Figure 15 (b).

FLUTTER STUDY OF SIMPLE BUSINESS JET WING CONDUCTED IN TDT FOR GULFSTREAM

Donald F. Keller
Aeroelasticity Branch

RTOP 505-63-50

Research Objective: A commercial business jet must be designed so that flutter will not occur within the flight envelope of the aircraft plus a 20-percent safety margin. Wind-tunnel tests of an aeroelastically-scaled model have traditionally been an important element in the design and certification of new aircraft. General aviation companies, however, often cannot afford to design and build a complex wind-tunnel flutter model. Computer analysis using accurate flutter prediction codes can therefore play an important role since many design parameters can be evaluated in a comparatively short time and at lower cost. The present study was a cooperative effort between NASA and Gulfstream to support flutter clearance of Gulfstream aircraft by obtaining experimental transonic flutter data on a simple and inexpensive flutter model. This data will be used to evaluate analytical flutter prediction codes, in particular CAP-TSD (Computational Aeroelasticity Program - Transonic Small Disturbance) which Gulfstream is using for the first time, for use in the design and certification of future Gulfstream aircraft. In addition, the present study was used to investigate the effects of a winglet on flutter of a business-jet class wing.

Approach: A simple semi-span model of a typical business jet was fabricated and tested in the Transonic Dynamics Tunnel (TDT) over a Mach number range of approximately 0.6 to 1.0 with air as the test medium. The model was designed so that it would flutter within the TDT operating envelope for air and have flutter characteristics similar to those of the actual aircraft. A photograph of the model mounted in the TDT test section is shown in the figure. The semi-span cantilevered wing consisted of an aluminum plate, whose thickness decreased in steps at intervals along the span, to which balsa wood was bonded and contoured to form a supercritical airfoil. A winglet canted outward at 15° was mounted at the wing-tip, and a wood fairing was used to provide more realistic wing root aerodynamics. The baseline configuration consisted of the wing, root fairing, and winglet. In addition, the model was tested without the winglet and with a tip boom intended to simulate the winglet mass with negligible aerodynamic effects.

Accomplishment Description: Flutter boundaries for the three configurations presented in the figure are plotted as normalized flutter dynamic pressure (Q/Q*) vs. Mach number, where Q* is the flutter dynamic pressure at Mach number 0.60 for the baseline configuration. The flutter boundary for the wing without the winglet was as much as 12 percent higher than the baseline configuration. The flutter boundary for the winglet simulator, however, was less than 5 percent lower than that for the baseline and indicated that winglet mass affected the flutter characteristics of the wing much more than winglet aerodynamics affected the flutter characteristics.

Significance: The results of this cooperative wind-tunnel test provide important data that will be useful in evaluating CAP-TSD and other flutter prediction codes for use in designing and certifying future Gulfstream aircraft. Also, the adverse effects of the winglet on the flutter of the model was shown to be primarily the result of its mass and not its aerodynamics, confirming results from past investigations of winglet effects on flutter.

Future Plans: Evaluation of the CAP-TSD, NASTRAN Doublet-Lattice, and Atlee-Cunningham kernel flutter prediction codes using the wind-tunnel test results is continuing. Experimental and analytical results will be published as a NASA formal report.

Figure 16 (a).

FLUTTER STUDY OF SIMPLE BUSINESS-JET WING CONDUCTED IN TDT FOR GULFSTREAM

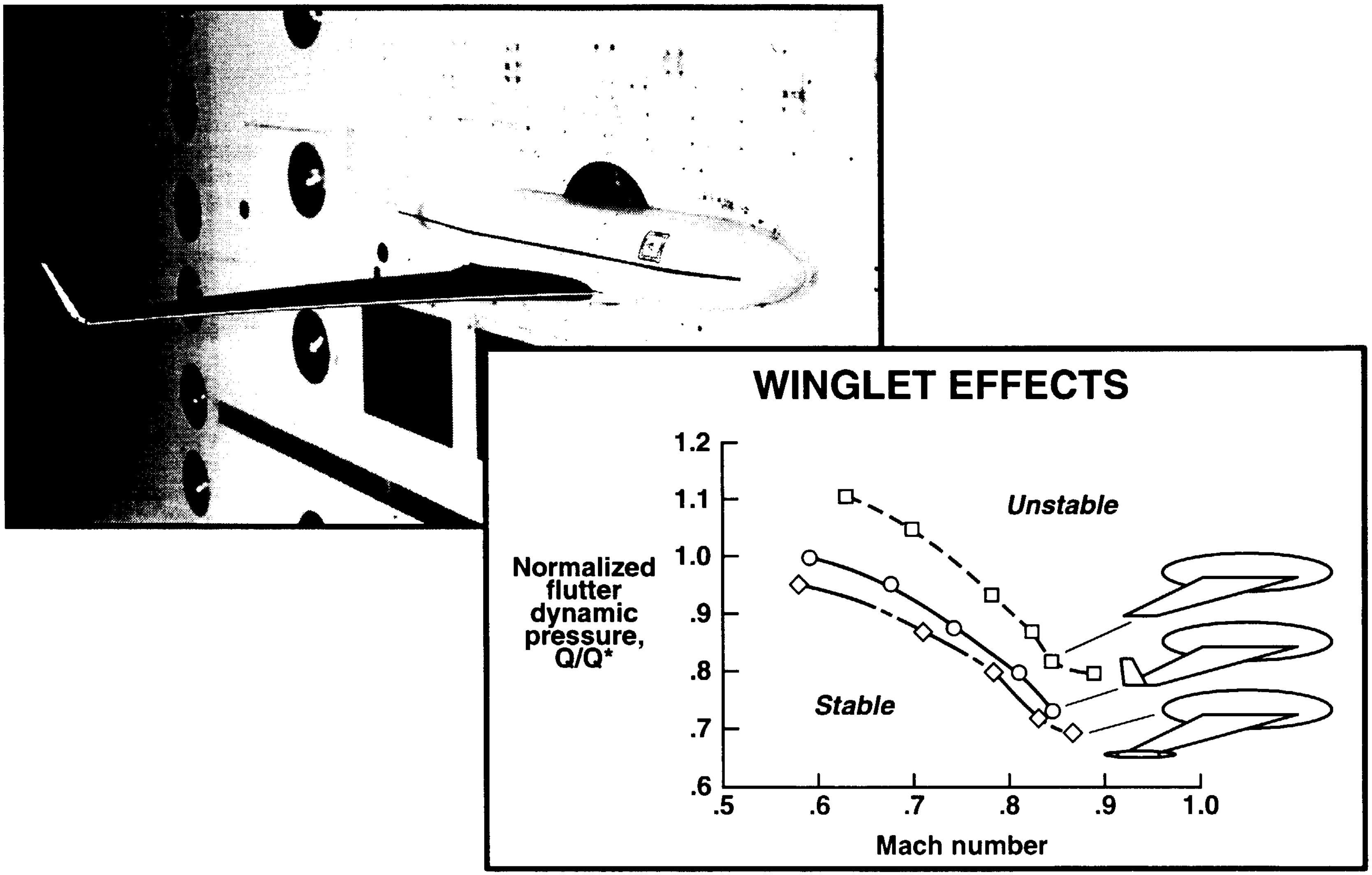


Figure 16 (b).

FLUTTER CHARACTERISTICS OF A FULL-SPAN NASP MODEL DETERMINED IN TDT

Stanley R. Cole
Aeroelasticity Branch

RTOP 505-63-50

Research Objective: The proposed National Aerospace Plane (NASP) consists of a long, flexible, lifting-body fuselage and relatively small, highly swept, all-movable, clipped-delta wings. The fuselage flexibility and the all-movable feature of the clipped-delta wings may make the vehicle susceptible to aeroelastic instabilities throughout the flight envelope. A wind-tunnel test of a NASP model was conducted to meet three objectives: to measure the flutter mechanism inherent to this type of vehicle; to examine the effect of parametric variations on the flutter behavior of the model; and to correlate the experimental data with analysis.

Approach: A tenth-scale representation of an unclassified version of the NASP vehicle was flutter tested in the Transonic Dynamics Tunnel (TDT). This representation was a full-span model with pitch and plunge degrees of freedom simulated with springs in the floor mount. The model had all-movable, clipped-delta wings and cantilevered, clipped-delta vertical fins. The stiffness of the wing actuators was simulated with springs. A photo of the model mounted in the wind tunnel is shown in the figure. A flutter analysis of the model was performed using calculated linear, lifting-surface aerodynamics.

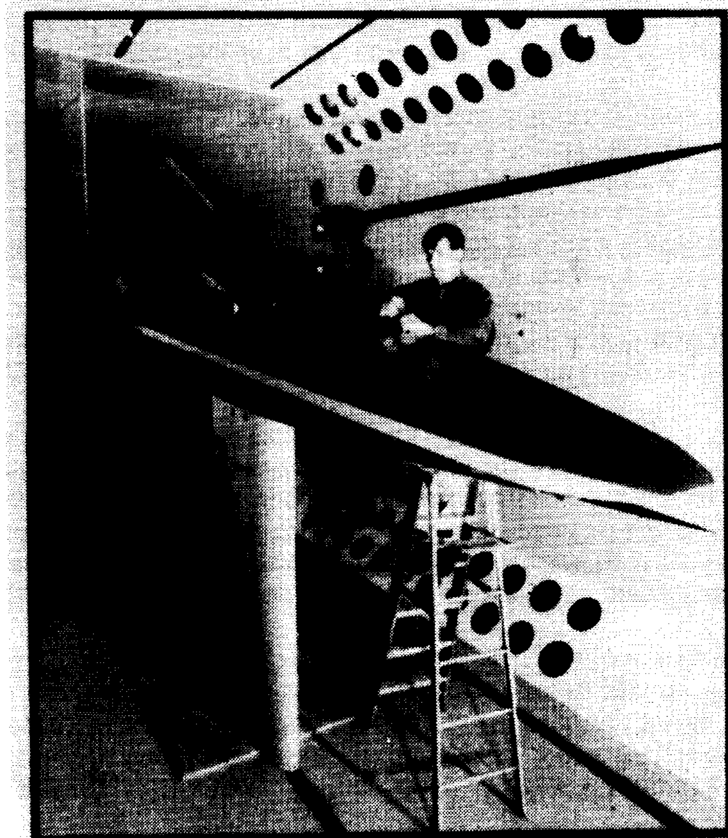
Accomplishment Description: Analytical and experimental results for two configurations of the model are shown in the figure. The first configuration was the baseline model. The parametric variation for the second configuration involved an increase in the wing-pivot stiffness. The primary flutter mechanism was body-freedom flutter involving the fuselage-pitch mode and the wing-pivot mode.
Flutter boundaries were analytically and experimentally determined for both configurations. The figure shows the experimental and analytical results in terms of dynamic pressure versus Mach number. The dynamic pressure has been normalized to the baseline-configuration-flutter point at Mach number 0.36. Experimental data were not obtained beyond Mach number 0.70 due to a single-degree-of-freedom flutter encountered with the all-movable wings. The flutter analysis for the baseline configuration matches the experimental data; however, the analysis is unconservative by approximately 10 percent in terms of dynamic pressure for the increased wing-actuator stiffness configuration. Both analysis and experiment show an increase in the flutter dynamic pressure with increased wing-actuator stiffness. Results of this study were presented at the AIAA 34th Structures, Structural Dynamics, and Materials Conference and at the 1993 NASP Technology Review.

Significance: The wind-tunnel test of this model showed that NASP-type vehicles employing single-pivot, all-movable wings are susceptible to body-freedom flutter. The test results show that increasing the wing-actuator-pitch stiffness can make the body-freedom flutter instability less critical. The correlation of flutter analysis to the experimental data indicates that the mathematical tools used in this study were sufficient to predict the body-freedom flutter encountered in the wind tunnel.

Future Plans: Results from the test and analysis are to be published in a NASP Contractor Report.

Figure 17 (a).

FLUTTER CHARACTERISTICS OF A FULL-SPAN NASP MODEL DETERMINED IN TDT



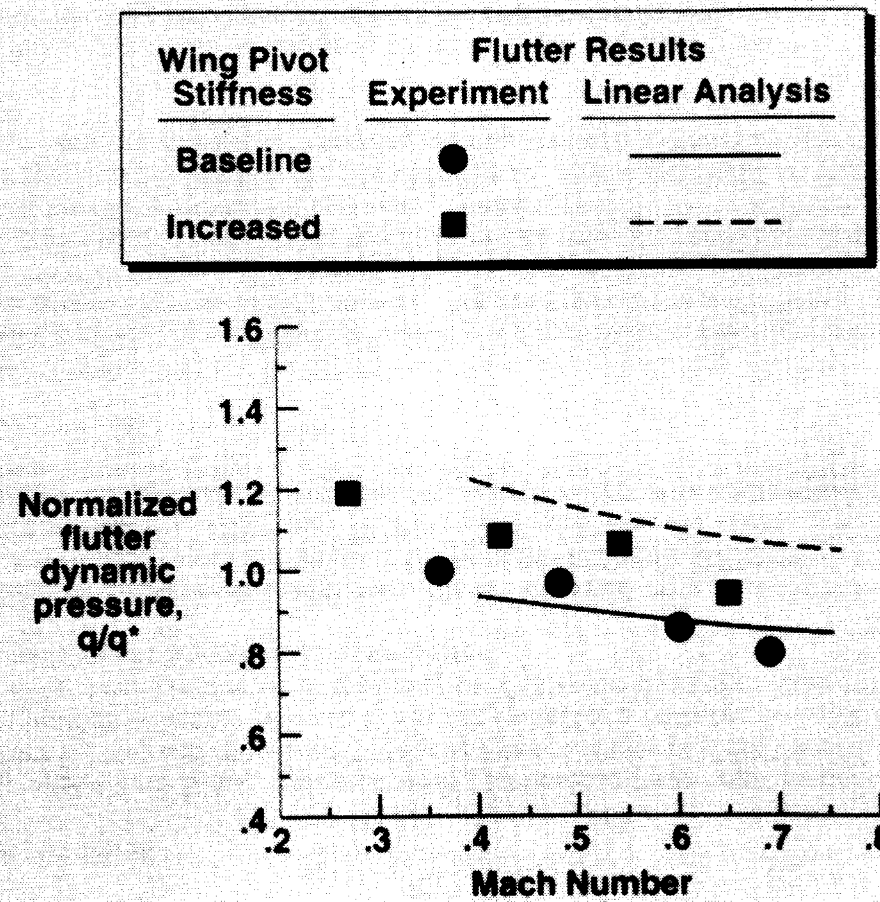


Figure 17 (b).

TDT TESTS CONDUCTED TO EVALUATE ADVANCED ROTOR BLADE TECHNOLOGY

William T. Yeager, Jr., Aeroelasticity Branch
Kevin W. Noonan, Army JRPO
Matthew L. Wilbur, Aeroelasticity Branch
Paul H. Mirick, Aeroelasticity Branch
Jeffrey D. Singleton, Aeroelasticity Branch

RTOP 505-63-36

Research Objective: In the fall of 1986, a Westland Helicopters Ltd. Lynx, equipped with paddle-type main rotor blades developed under the British Experimental Rotor Program (BERP), claimed the Class E-1 (helicopters without payload) speed record. Westland has claimed that the BERP rotor blades can provide either an increase in aircraft speed for a constant thrust or an increase in load factor for a constant aircraft speed. A test has been conducted in the Langley Transonic Dynamics Tunnel (TDT) to acquire data to evaluate the BERP planform using aeroelastically scaled model rotor blades.

Approach: A test was conducted in the TDT using baseline and BERP-type model rotor blades mounted on a four-bladed articulated hub. The term "BERP-type" is used because of the difference in airfoil sections between the full-scale BERP blades and the model BERP-type blades. The planform geometry for both the BERP and BERP-type blades was the same. The baseline and BERP-type blades used the same RC-series airfoils, the same radial distribution of airfoils, the same radial twist distribution, and the same thrust-weighted solidity. Rotor performance and fixed-system vibratory loads data were acquired for each blade set over a range of rotor lift coefficients, rotor drag coefficients, and advance ratios.

Accomplishment Description: The performance improvements claimed for the BERP planform were evaluated by cross-plotting data to a nominal design condition of 4,000 feet altitude and 95 degrees Fahrenheit ambient temperature for a rotor task representative of the Army UH - 60 Blackhawk helicopter at a gross weight of 18,500 pounds. The data indicate that the BERP-type planform, compared to a baseline rectangular planform, provides increases in speed for a fixed rotor thrust (not shown). The enclosed figure contains a plot of rotor torque coefficient, a measure of rotor power required, versus rotor lift coefficient and shows that the BERP-type blade also provides an increased load factor capability at a constant advance ratio of 0.30. In addition, data obtained from a previous TDT test are also plotted for comparison purposes on the enclosed figure. These data indicate that a Langley-designed Growth Blackhawk (GBH) tapered blade planform provides performance improvements over the BERP planform in terms of power requirements and lifting capability.

Significance: Because the next generation of U.S. Army helicopters will be required to be fast, maneuverable, and carry increased payloads, it is imperative that all rotor blade design technology be evaluated as possible enhancements to current U.S. industry rotor design methods.

Future Plans: Future plans call for documentation of these rotor performance results and the accompanying fixed-system vibratory loads data in a NASA formal report.

Figure 18 (a).

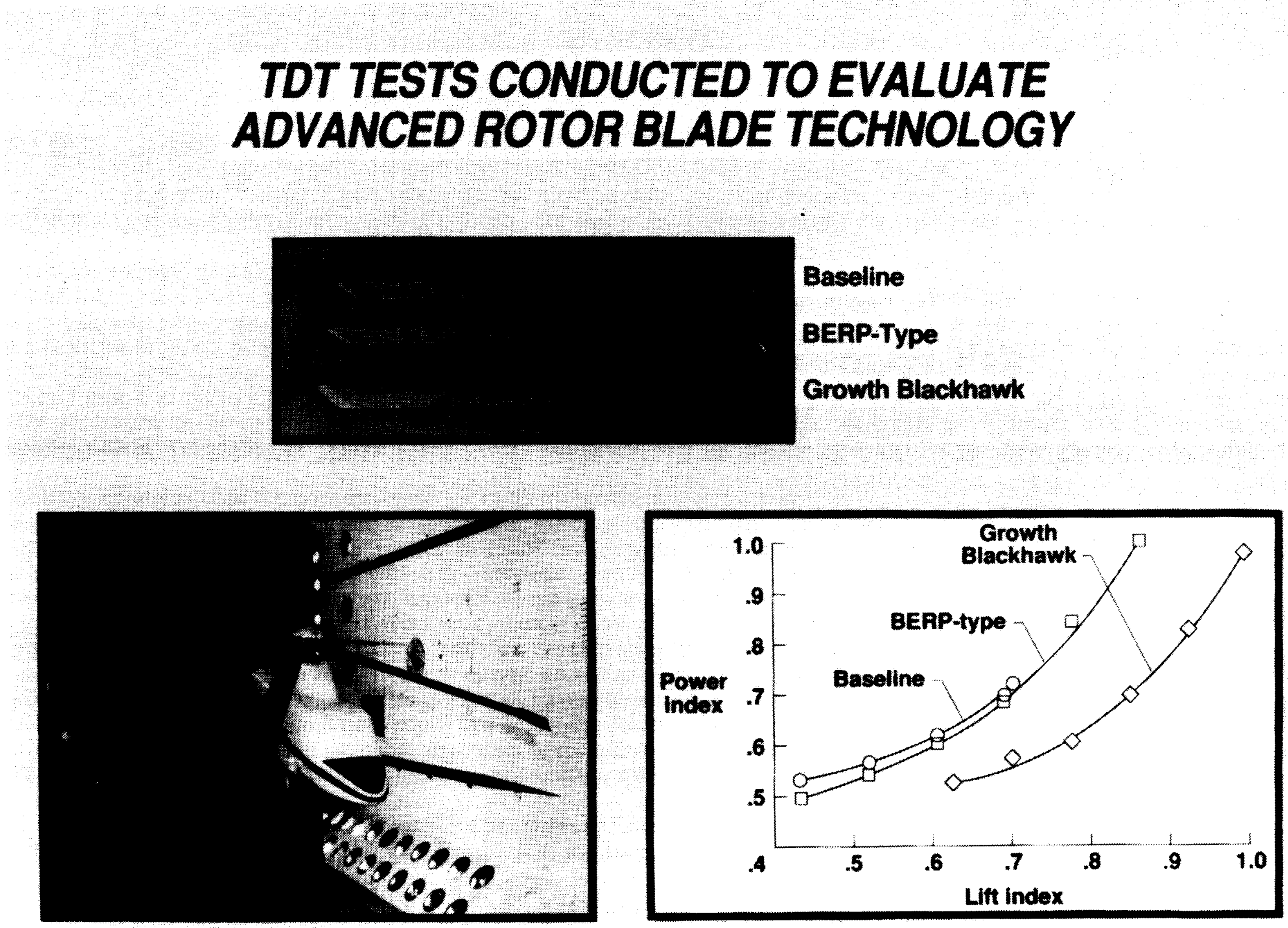

TDT TESTS CONDUCTED TO EVALUATE
ADVANCED ROTOR BLADE TECHNOLOGY
Baseline
BERP-Type
Growth Blackhawk
Power Index
1.0
.9
.8
.7
.6
.5
.4
.5
.6
.7
.8
.9
1.0
Lift index
Baseline
BERP-type
Growth Blackhawk

Figure 18 (b).

ALGORITHM DEVELOPED FOR THE FAA THAT COMPUTES DESIGN GUST LOADS FOR NONLINEAR AIRCRAFT

Robert C. Scott
Aeroelasticity Branch

RTOP 505-63-50

Research Objective: The objective of this activity was to provide to the FAA a transportable computer code, and supporting documentation, for computing design gust loads for nonlinear aircraft.

Approach: The accompanying figure illustrates a chronology of the NASA-developed methods for computing maximized and time-correlated gust loads. Beginning in the upper left corner of the figure and moving diagonally down, matched-filter theory (MFT) was developed as a method of predicting time-correlated gust loads for linear aircraft. MFT was then extended to nonlinear aircraft by employing two approaches: a matched-filter-based (MFB) one-dimensional search approach and an MFB multi-dimensional search approach. The MFB method then suggested a stochastic-simulation-based (SSB) method, which also has two approaches within it: an SSB straight-average approach and an SSB weighted-average approach. The SSB straight-average approach was developed first; the SSB weighted-average approach was under development (indicated by the crosshatching in the figure) when NASA and the FAA began discussing the possibility of NASA providing to the FAA a transportable computer code for obtaining design gust loads for nonlinear aircraft. NASA and the FAA signed an agreement with three tasks: Task 1 (see figure) was to complete the development of the SSB weighted-average approach, thereby bringing the MFB and SSB methods to the same level of maturity; Task 2 was to compare the MFB and SSB methods and to recommend the method best suited for nonlinear analyses; and Task 3 was to develop a transportable computer code and documentation for using the recommended method.

Accomplishment Description: Tasks 1 and 2 were completed and the results presented at the Gust Specialists Meeting in LaJolla, California on April 22, 1993. At the meeting NASA recommended the MFB one-dimensional search approach for computing time-correlated gust loads for aircraft with nonlinear systems. Since April, a transportable FORTRAN 77 code was developed and documentation was written. This code is depicted at the bottom of the accompanying figure. To run the code the user must provide an input file and a subroutine containing the nonlinear aircraft equations of motion. The code first reads the input file and then performs simulations obtaining impulse responses of the airplane model. The impulse responses are then used to create excitation waveforms which are reapplied to the user-supplied aircraft equations of motion. Maximized and time-correlated load quantities are obtained as output.

Significance: The transportable algorithm developed here will be provided to aircraft manufacturers for independent evaluation. Ultimately, the method may simplify the analysis and certification of aircraft with nonlinear control systems.

Future Plans: The supporting documentation for the transportable code will be published as an FAA Technical Report.

Figure 19 (a).

ALGORITHM DEVELOPED FOR THE FAA THAT COMPUTES DESIGN GUST LOADS FOR NONLINEAR AIRCRAFT

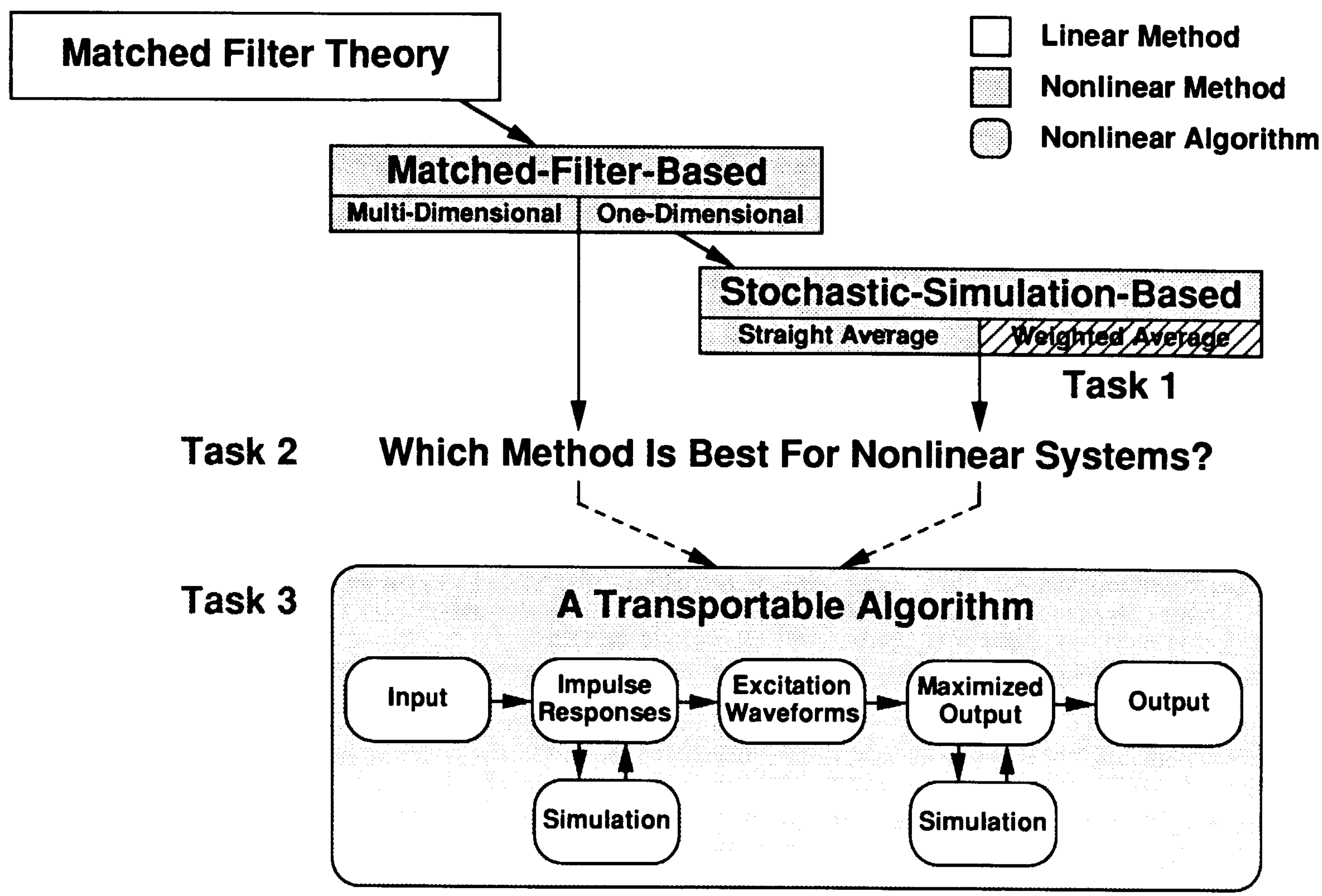


Figure 19 (b).

BENDING-TWIST-COUPLED ROTOR BLADE IMPROVES TILTROTOR STABILITY

Mark W. Nixon
Aeroelasticity Branch
RTOP 505-63-50

Research Objective: The objective of this research is to investigate the effect of rotor blade elastic bending-twist coupling on tiltrotor system stability in the high-speed airplane mode of flight.

Approach: The present study considers the influence of introducing bending-twist coupling into the rotor blades of an uncoupled baseline tiltrotor system, the Bell full-scale, 25-ft diameter proprotor with stiff-yoke hub mounted on a cantilever wing. Baseline results were first used to validate a new comprehensive analysis formulated in-house for the study of tiltrotor systems with elastically-coupled rotor blades. For the stability part of the investigation, realistic limits were established for the magnitude of elastic coupling which could be introduced into the blade structure. Here, the beam stiffness properties of the metal baseline were matched using a composite cross section model. The cross section model was composed of graphite/epoxy cloth material such that orientation of the fiber angles off-axis with respect to the spanwise direction invoked bending-twist coupling. A convenient parameter (ψ) was used to gage the magnitude of the desired bending-twist coupling stiffness relative to the classical beam stiffnesses, and guidelines for the magnitude of this parameter were established for use in the study, as is illustrated in the lower left corner of the figure. Tiltrotor stability was then assessed using the baseline blade stiffness properties in conjunction with realistic magnitudes of bending-twist coupling stiffness.

Accomplishment Description: A highly destabilizing feature of the baseline tiltrotor system is the rotor precone which is designed to reduce blade stress levels in hover mode. In high-speed airplane mode, however, the force balance between lift and centrifugal forces is altered such that the rotor precone introduces high levels of negative pitch-lag coupling into the blade system. This coupling is analogous to wash-in on fixed-wing systems because the flatwise part of the blade is closely aligned to the lag direction at high speeds. In the present study, the coupling due to the precone is counteracted by an opposing elastic bending-twist coupling, which produces washout of the blade twist, as illustrated in the upper left corner of the figure. The magnitudes of bending-twist coupling considered in the study are well within the range of typical structural limitations as is illustrated in the lower left corner of the figure. The predominant mode of instability for the tiltrotor in high-speed flight is the wing beam-bending mode (which is highly coupled to the rotor system). The influence of introducing the elastic coupling into the blade system is shown on the plot on the right side of the figure. The uncoupled baseline system becomes unstable at about 250 knots. The increased use of elastic coupling is shown to increase the damping levels of the wing mode and increase the flutter velocity up to about 375 knots at the higher magnitude of coupling parameter considered.

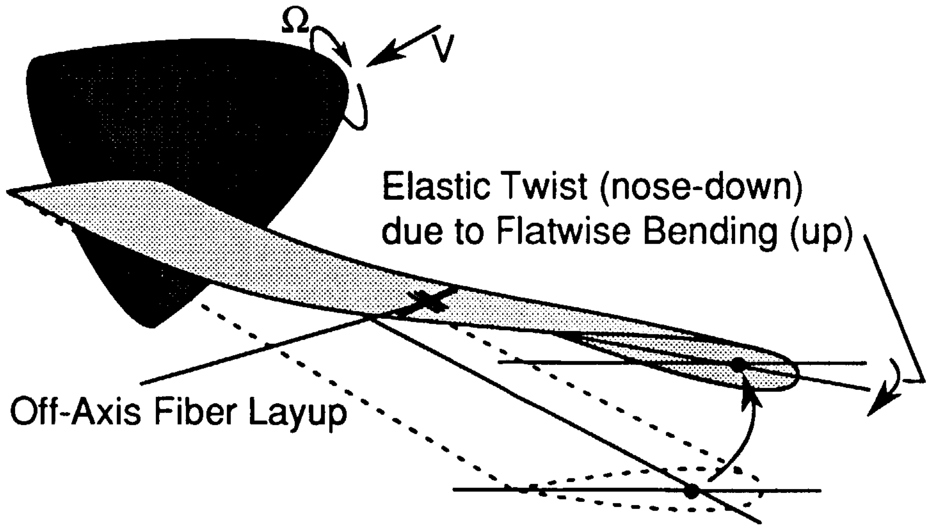
Significance: This research shows that, compared to a baseline tiltrotor system, bending-twist-coupled tiltrotor blades can significantly improve stability characteristics. The concept investigated here may lead to an expanded flight envelope for future production tiltrotor aircraft.

Future Plans: Present tiltrotor designs use a flexured-yoke hub which reduces the adverse precone effect on stability in high-speed flight. An investigation is planned to determine if the bending-twist coupling concept of this study has a significant influence on stability of systems with a flexured-yoke hub.

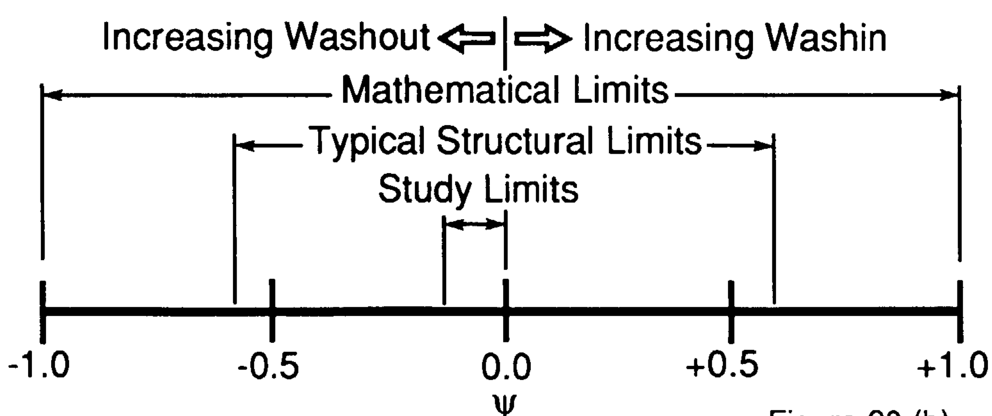
Figure 20 (a).

BENDING-TWIST-COUPLED ROTOR BLADE IMPROVES TILTROTOR STABILITY

Bending-Twist-Coupled Blade



Bending-Twist-Coupling Parameter (ψ)



Stability of Wing Beam-Bending Mode

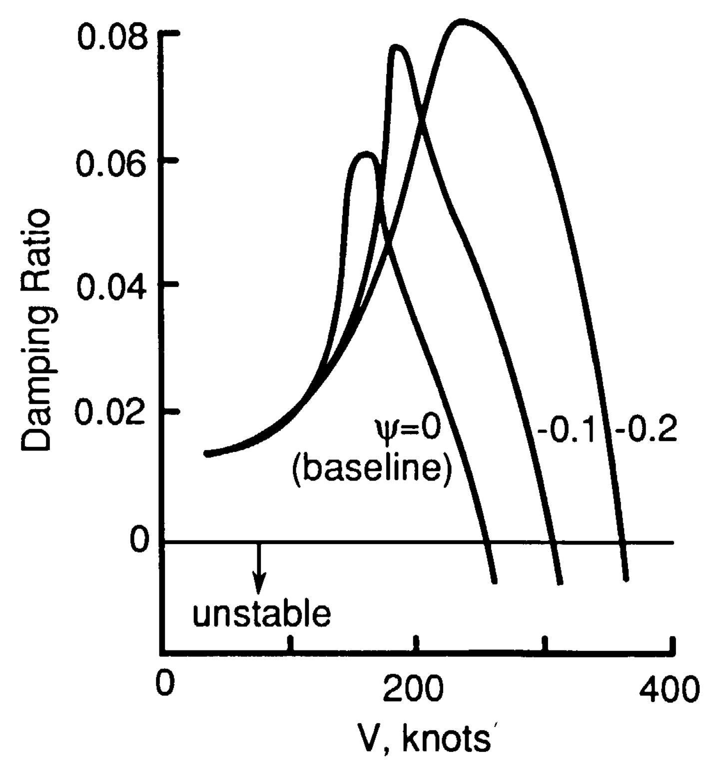


Figure 20 (b).

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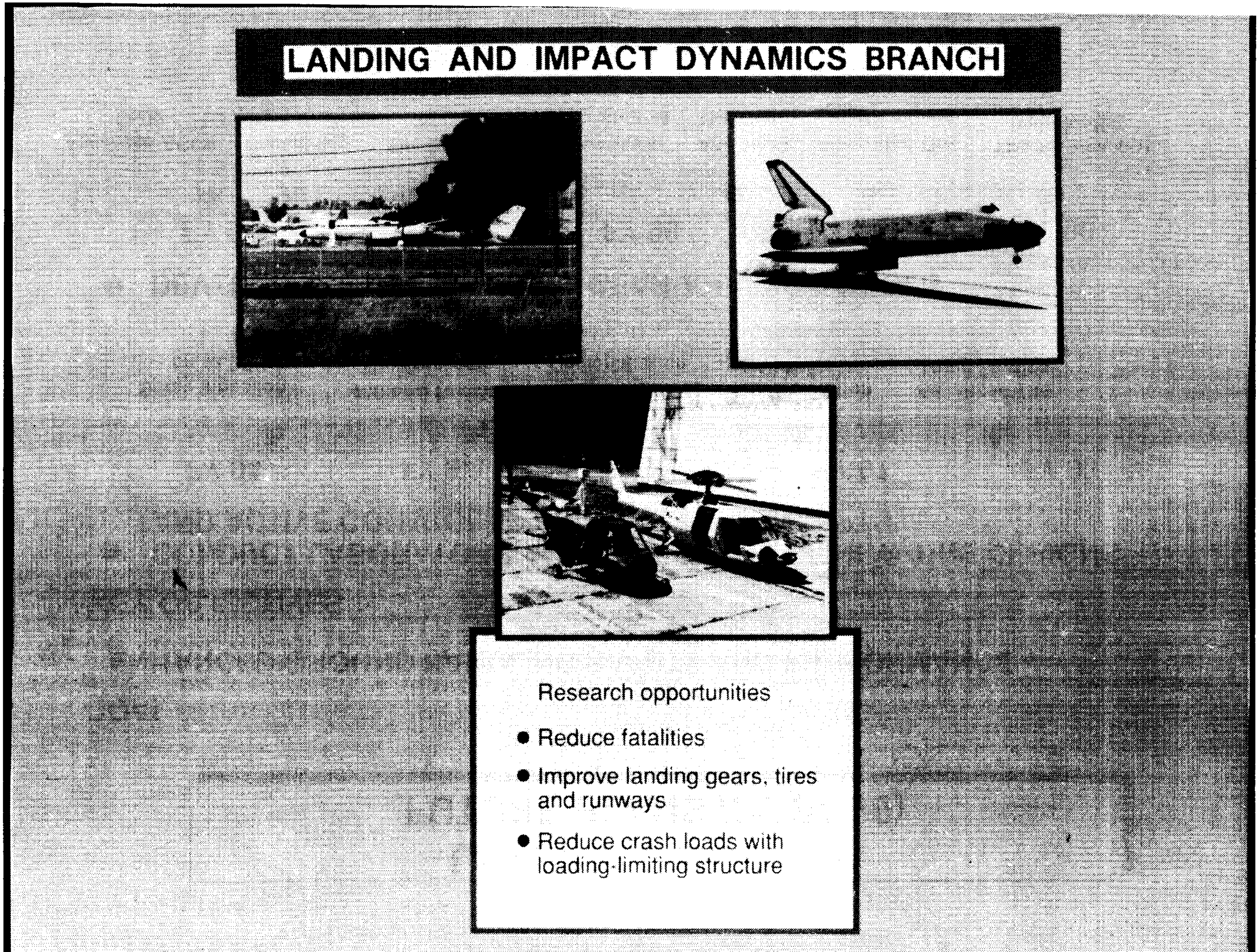

LANDING AND IMPACT DYNAMICS BRANCH
Research opportunities
• Reduce fatalities
• Improve landing gears, tires and runways
• Reduce crash loads with loading-limiting structure

Figure 21.

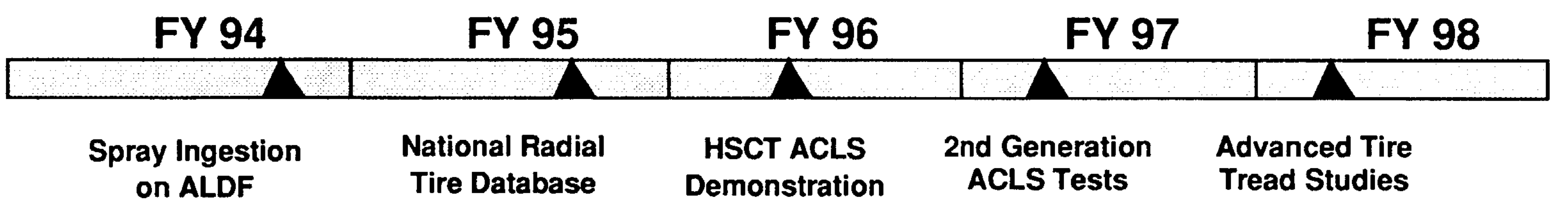
LANDING DYNAMICS
FUTURE PLANS (FY 94-98)

GOAL

ENHANCED GROUND HANDLING SAFETY AND PERFORMANCE

KEY OBJECTIVES

- CONDUCT LABORATORY AND ALDF TESTS OF NEW TIRE DESIGNS AND ACTIVE CONTROL LANDING GEAR CONCEPTS



- DEVELOP TIRE AND LANDING GEAR ANALYSIS TOOLS

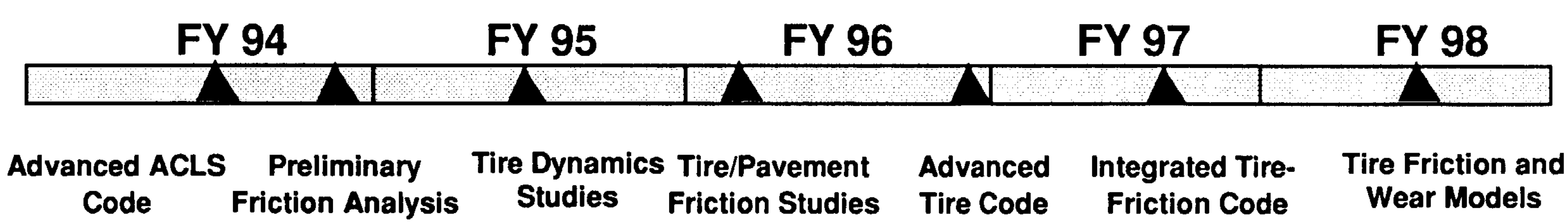


Figure 22 (a).

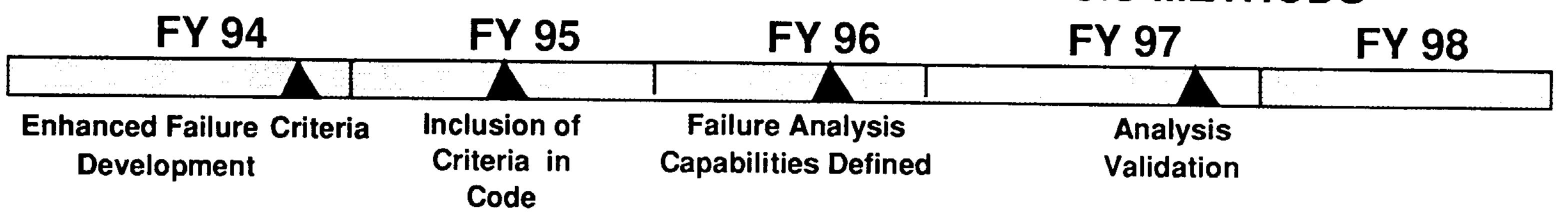
IMPACT DYNAMICS
FUTURE PLANS (FY 94-98)

GOAL

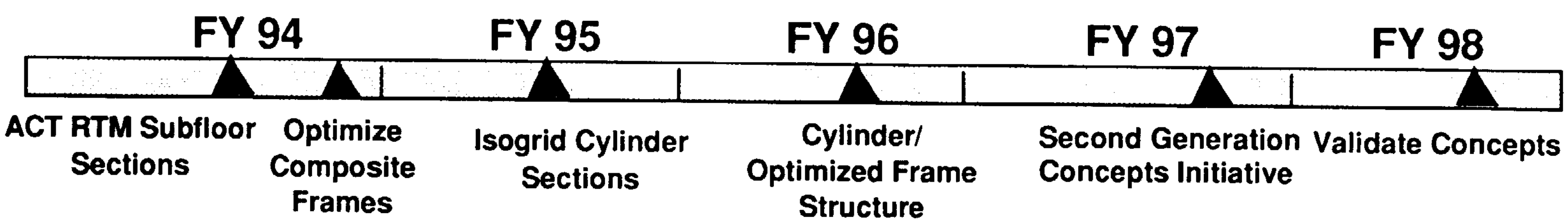
FUNDAMENTAL UNDERSTANDING OF COMPOSITE CRASH BEHAVIOR AND IMPROVED CRASHWORTHY DESIGNS

KEY OBJECTIVES

- DEVELOP NONLINEAR STRUCTURAL ANALYSIS METHODS



- DEFINE DATA BASE FOR COMPOSITE STRUCTURES



- CONDUCT FULL-SCALE TESTS OF AIRFRAME CONCEPTS

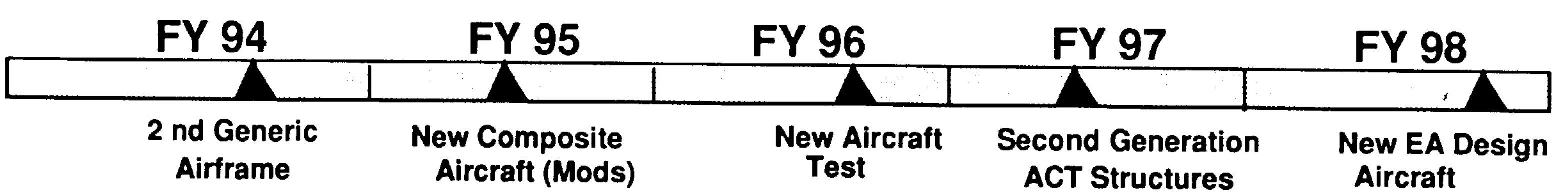


Figure 22 (b).

COMPOSITE SCALING STUDIES PROVIDE A VARIETY OF IMPORTANT SPIN-OFFS

Karen E. Jackson, U.S. Army Vehicle Structures Directorate, ARL

RTOP 505-63-50-09

Research Objective: Define the effect of size of a composite laminate on ply failure stress and ultimate strength under tensile loading conditions.

Approach: In one study, tensile tests were conducted on geometrically scaled angle ply laminates which were fabricated using two different scaling approaches. In the first approach plies of similar orientation were blocked together . In the second approach the ply orientations were distributed throughout the laminate thickness. A second study was conducted to investigate the effect of specimen size on the tensile response and ultimate failure in blocked and distributed scaled composite coupons. All lay-ups contained a core of 90° plies which tend to develop transverse matrix cracks under tensile loading. These cracks act as stress risers in neighboring plies leading to premature fiber failure, or serve as sites of delamination initiation.

Accomplishment Description: Stress/strain data from scaled angle ply coupons loaded in tension to failure are shown in the left figure. All scaled specimens exhibit the same initial modulus. However, a significant scale effect in strength is observed as size increases, the scaled coupons containing blocked plies exhibit a trend of decreasing strength. Thus, the baseline, or smallest specimen, appears twice as strong as the comparable full-scale specimen. For the distributed ply specimens, the trend is increasing strength with increasing specimen size. Also, the distributed ply lay-ups have a plastic, yielding behavior, while the blocked lay-ups exhibit a brittle response prior to failure. The data in the right figure show critical strains at the onset of transverse matrix cracking in the 90° plies and at the onset of delamination for quasi-isotropic laminates as a function of increasing size. Also shown are analysis results for delamination onset using a strain energy release rate approach which predicts a highly conservative failure strain magnitude compared to the experimental data. As a first approximation to account for matrix cracking, the experimental data for onset of transverse cracking was added to the delamination analysis illustrated in the figure. This summation appears to more accurately represent strain at delamination onset with specimen size.

Significance: As a result of these findings and recommendations, the ASTM D-3518 standard test method for determination of shear modulus and shear strength has been changed to specify a minimum thickness and lay-up for the tests specimens. The International standard is expected to follow. Results of the second study are being used to challenge current failure theories to attempt to account for size effects or the importance of transverse cracking in predicting delamination onset.

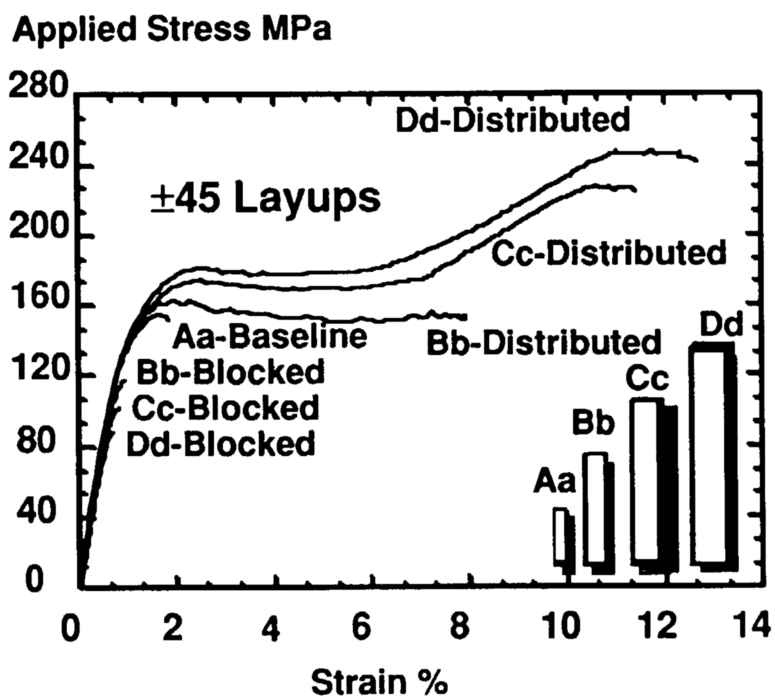
Future Plans: Conduct necessary tests to understand the influence of cracking on ultimate onset of delamination and attempt to improve failure theories to account for matrix cracking in predicting onset of delamination regardless of specimen size.

Figure 23 (a).

COMPOSITE SCALING STUDIES PROVIDE A VARIETY OF IMPORTANT SPIN-OFFS

Materials Mechanical Properties

- ASTM Standard Revised For ± 45° Shear Test.
- Internaltional Standard Expected To Follow.



Failure Theory Evaluation

- Scale Effects In First-Ply Failure Stress Highlights Need to Improve Failure Theories

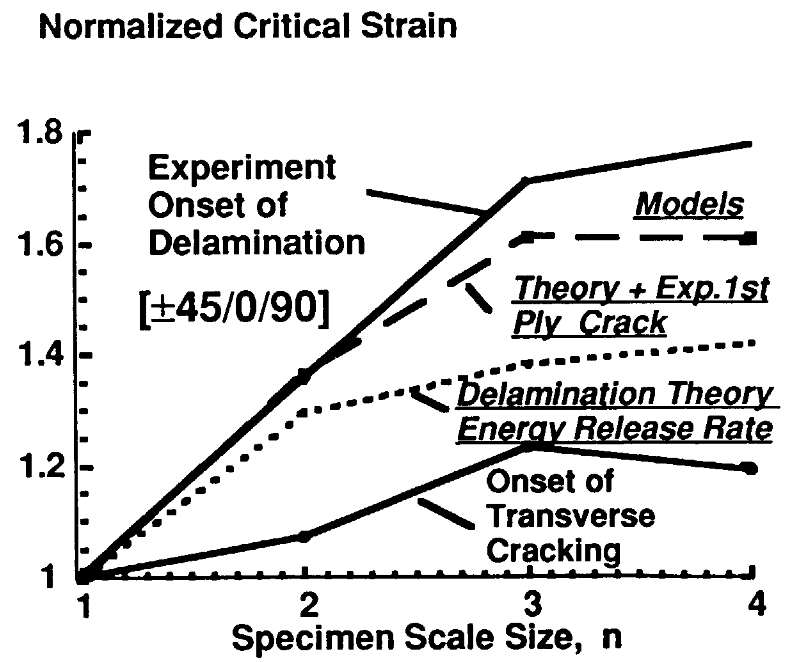


Figure 23 (b).

ENERGY ABSORBING CHARACTERISTICS OF A COMPOSITE FUSELAGE SECTION DEFINED

Huey D. Carden, Lisa E. Jones, and Sotiris Kellas (LESC)

RTOP 505-63-50-09

Objective: To verify experimentally the energy absorbing characteristics of a composite fuselage.

Approach: A dynamic test was carried out on a (5 ft diameter) composite fuselage section removed from a basically all composite, eight seat airplane, with a gross takeoff weight of about 7200 lb. and empty weight of 4000 lb. that has been acquired for testing. The aircraft is a composite skin/frame construction with the exception of the subfloor structure which contains four aluminum spars. The section had two frames, approximately 5 1/2 inches apart, one of which was adjacent to an original door cutout. The section was fitted with two aluminum platforms weighing 12 pounds each. An additional 100 pounds mass was attached to each platform surface representing about half of a seat/occupant mass. Each platform was fastened through seat attachments to the original rails of the unmodified aircraft. The section, shown in the figure was dropped from a height of 15 ft. and reached a velocity of approximately 30 fps at the time of impact. Seat-rail acceleration responses are also presented in the figure.

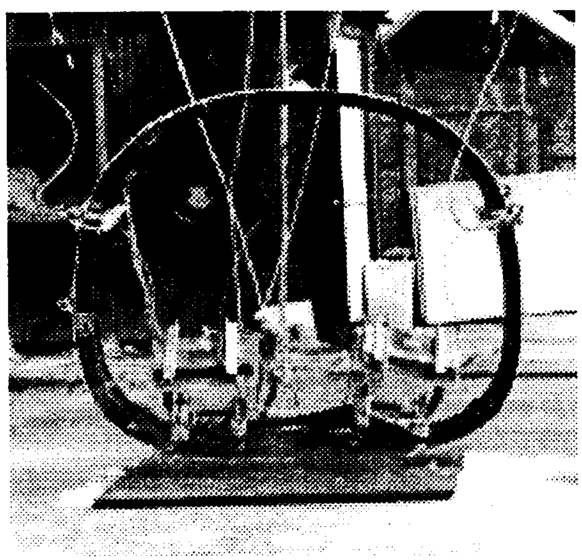
Accomplishment Description: The test indicated that the amplitude and duration of the seat-rail pulse ($\approx$ 50-120 Gs for 6 ms) is more severe than generally acceptable levels. Typically, to avoid fatalities and/or severe injury, the seat-rail acceleration should be limited to approximately 25-60 Gs, or less, for a minimum period of 12 ms. The test results highlighted the need for crash load attenuation through the use of energy absorbing subfloor structure and/or energy absorbing seats.

Significance: Fuselage section and full airframe crash tests of composite aircraft will define energy the absorbing characteristics to be integrated into the design of more crashworthy aircraft structures. These energy absorbing characteristics will also have applications to the automotive industry.

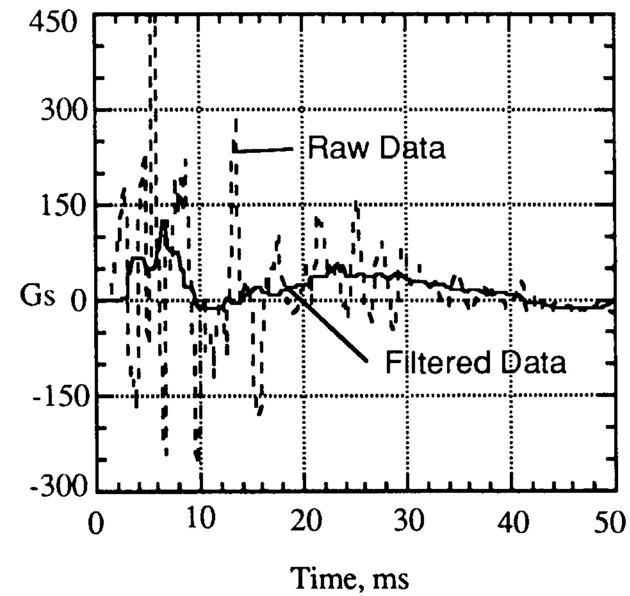
Future Plans: The LaRC Impact Dynamics Research Facility will be used to conduct full-scale crash tests of two composite airframes. These tests will evaluate proposed energy absorbing subfloor concepts and improved seat designs.

Figure 24 (a).

ENERGY ABSORBING CHARACTERISTICS OF A COMPOSITE FUSELAGE SECTION DEFINED



Section during test



Seat-Rail Response

Figure 24 (b).

IMPROVED SAFETY OF HELICOPTER FUEL BLADDERS

Richard L. Boitnott and Akif O. Bolukbasi (McDonnell Douglas Helicopter Systems)

RTOP 505-63-50-09

Objective: To determine the effect of energy absorbing materials surrounding a drop tested fuel bladder.

Approach: A Cooperative Research and Development Agreement (CRDA) was established with McDonnell Douglas Helicopter Systems (MDHS) to study the response of fuel bladders to simulated crash test conditions. The purpose of these tests was to determine if energy absorbing (EA) materials placed adjacent to the fuel bladder could absorb the kinetic energy of the fuel and reduce internal pressures generated during crashes. High crash pressures may result in catastrophic failure of primary structures and/or reduction of the energy absorption capability of the airframe. In addition, the high internal hydrodynamic pressures are more likely to result in fuel leakage and pose a post-crash fire hazard. In this study a single fuel bladder was used in five drops. Four of the tests were conducted with the bladder placed inside of a steel box. The difference in size between the box and bladder allowed EA material to be placed around the sides and the bottom of the bladder. Different approaches which may be used to absorb the kinetic energy of the fuel such as placing honeycomb on the sides and bottom were evaluated. In other cases, sheets of plywood were used as a rigid filler on the sides of the box. The bladder was also dropped by itself without any lateral constraint other than what the bladder material itself provided. The primary data collected during these tests were the internal pressures and the crushing of the EA material. Bottom pressure time-history plots are shown in the attached figure for tests with and without EA materials on the sides. Both tests had bottom EA material.

Accomplishment Description: The finding illustrated in the figure shows he effect of side EA materials on the internal pressure of the bladder. The pressure in Test 5 without side EA material rapidly increases to approximately 140 psi during the crash pulse. The pressure in Test 1 with additional side EA material never increased above 50 psi. In other tests without any bottom EA materials bladder pressures of 340 psi were recorded.

Significance: These results indicate that EA materials placed around the fuel bladder reduce the internal hydrodynamic pressure during a crash and reduce the potential fire hazard. Implementation of this technology into future helicopter designs will have a significance effect on flight safety.

Future Plans: Additional tests at various drop heights and with different EA materials are planned. A dynamic finite-element analysis of the fuel bladder and the surrounding material is also planned. The finite-element model will consist of shell elements for the bladder, solid elements with a elasto-plastic hydrodynamics materials model for the fuel, and a crushable model for the EA material.

Figure 25 (a).

IMPROVED SAFETY OF HELICOPTER FUEL BLADDERS

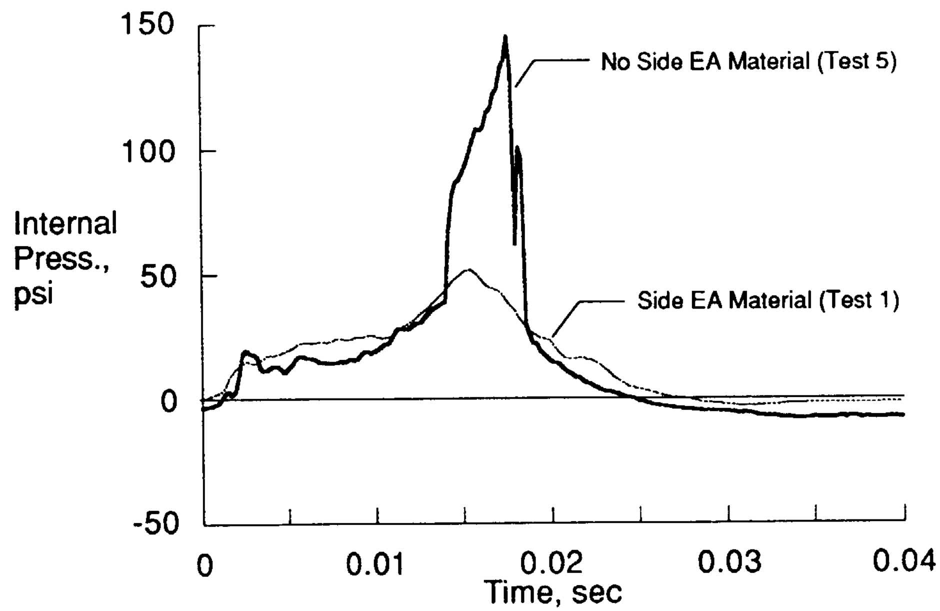


Figure 25 (b).

H46X18-20 BIAS-PLY AND RADIAL-BELTED TIRE CHARACTERISTICS DEFINED

Pamela A. Davis and William E. Howell

RTOP 505-63-10-02

Research Objective: The research objective is to study the surface traction characteristics of an H46X18-20 aircraft tire in both a bias-ply and radial-belted design and compare these properties.

Approach: Two different H46X18-20 tire designs have been tested at the Aircraft Landing Dynamics Facility (ALDF). The two tire designs were tested on dry and wet surface conditions, at various yaw angles and speeds in order to define the friction characteristics of the different tire types.

Accomplishment Description: The H46X18-20 size aircraft tire, which is the main gear tire on the Boeing 767 series airplane, has been tested in a bias-ply and radial-belted design at the ALDF. Both static load-deflection tests and cornering tests have been conducted. The cornering characteristics of these two tire types on a wet runway surface at 160 knots are shown in the attached figure at a vertical load of 44 000 lb. Up to a 4° yaw angle, both tire types exhibit similar cornering-force friction characteristics. For yaw angles above 4°, the bias-ply tire produces higher friction coefficient values than the radial tire. This characteristic was observed to continue up to a 12° yaw angle, the maximum yaw angle tested. These results indicate that under crosswind landing conditions on a wet runway surface, the bias-ply tire would provide more friction between tire footprint and pavement than the radial tire for higher yaw angles.

Significance: The information shown in the attached figure will help to establish a national database for radial-belted aircraft tires that will be used to compare their mechanical properties and friction characteristics with those of bias-ply tires. This information will be used by tire manufacturers to improve their tire designs. These data will eventually be used by aircraft operators to enhance aircraft safety during ground operations under adverse weather conditions.

Future Plans: Further analysis of the free rolling and braking data on dry and wet surfaces at various speeds and yaw angles will further define the surface traction characteristics of the two tire designs. This information will be documented in a reference publication to be used as a landing gear design guide.

Figure 26 (a).

H46X18-20 BIAS-PLY AND RADIAL-BELTED TIRE CHARACTERISTICS DEFINED
TIRE LOAD: 44,000 LB.; VELOCITY: 160 KT.

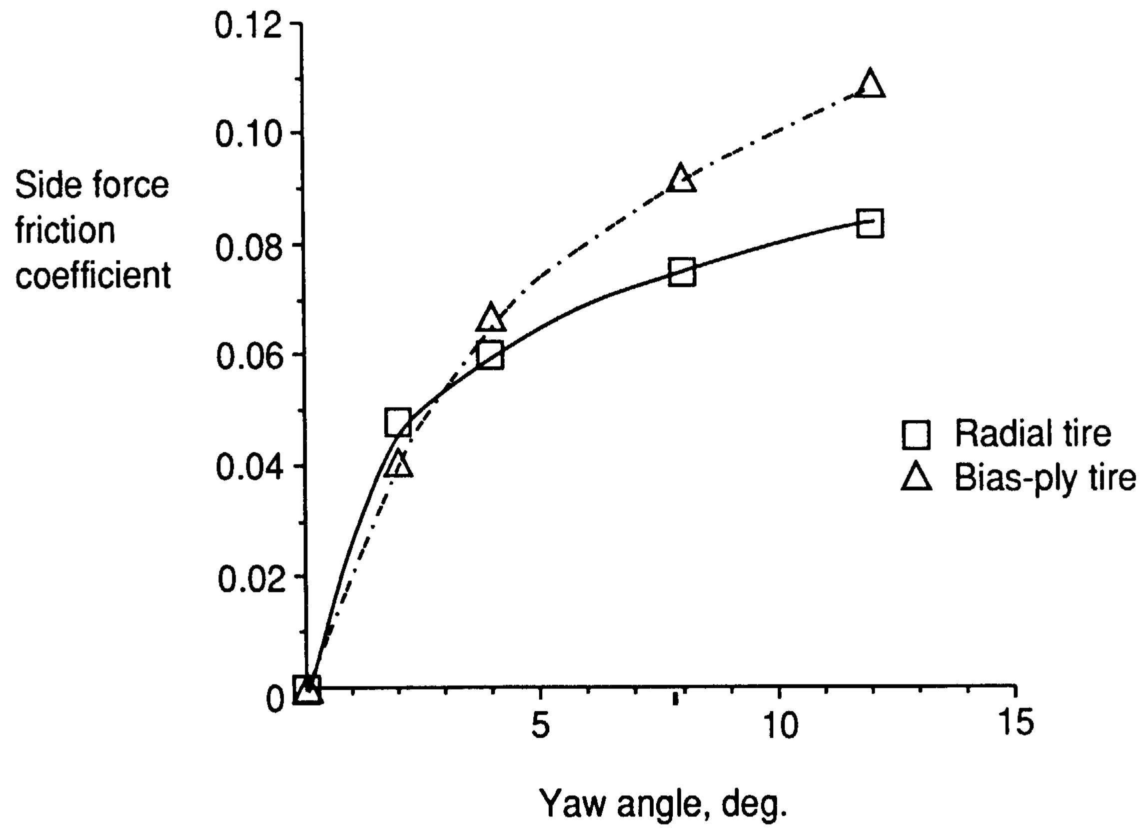


Figure 26 (b).

EFFECTS OF TYPE II DE-ICER FLUID ON AIRCRAFT TIRE FICTION DETERMINED IN ALDF TESTS

Thomas J. Yager, Sandy M. Stubbs, Granville L. Webb, and William E. Howell

RTOP 505-63-10-02

__Research Objective__: The research objectives of this joint NASA/FAA/Industry program are to evaluate factors influencing aircraft-tire/runway-friction performance on pavements contaminated with Type II chemical de-icer depositions and to identify the magnitude of friction degradation for different aircraft tire operational conditions.

__Approach__: Tests were conducted at the Aircraft Landing Dynamics Facility (ALDF) with financial support provided by the FAA under an existing Memorandum of Agreement. A conventional, 40x14 transport aircraft main gear tire was tested at speeds up to 160 knots ground speed on a non-grooved concrete test surface. Surface test conditions included dry, wet (water only), Type II chemical/water mixture, and 100 percent Type II chemical. Test tire operational modes included anti-skid controlled braking at zero yaw angle and yawed rolling at fixed 6°-yaw angle.

__Accomplishment Description__: Initial ALDF tests to determine the variation of tire cornering friction performance with speed and surface condition have been completed. A typical example of the variation of tire/pavement side force friction coefficient μ_s shown in the attached figure for four different surface conditions--dry concrete, water-wet concrete, 3-parts-water to 1-part de-icer wet concrete, and 100-percent de-icer wet concrete. These data were obtained during the same 100-knot test run. A section of dry concrete was provided between the liquid contaminated surfaces. The results indicate that for the 3-to-1 mixture the friction values are similar to the water-wet condition. The friction coefficient for 100-percent de-icer was about 30 percent lower than the water-wet value. The 3-to-1 mixture is probably more representative than the 100-percent mixture of what might be found in normal aircraft operations. Therefore, these results suggest that, in practice, the de-icer effects on friction will be similar to those of water.

__Significance__: The information such as that shown in the figure will assist in establishing a national database on effects of aircraft Type II chemical de-icer depositions on aircraft-tire/pavement friction performance. These data will also help improve safety of aircraft ground operations during winter runway conditions.

__Future Plans__: Additional tests at NASA Wallops Flight Facility using Langley's Instrumented Tire Test Vehicle (ITTV) will be conducted to examine tire bearing pressure and pavement transverse grooving effects. Additional tests are under consideration for next winter to evaluate effects of ambient temperature variations and define the frictional properties of different aircraft chemical de-icers. Test results will be published in a formal NASA publication.

Figure 27 (a).

EFFECTS OF TYPE II DE-ICER FLUID ON AIRCRAFT TIRE FRICTION DETERMINED IN ALDF TESTS

40 X 14 TIRE; SPEED = 100 KNOTS; YAW ANGLE = 6 DEGREES

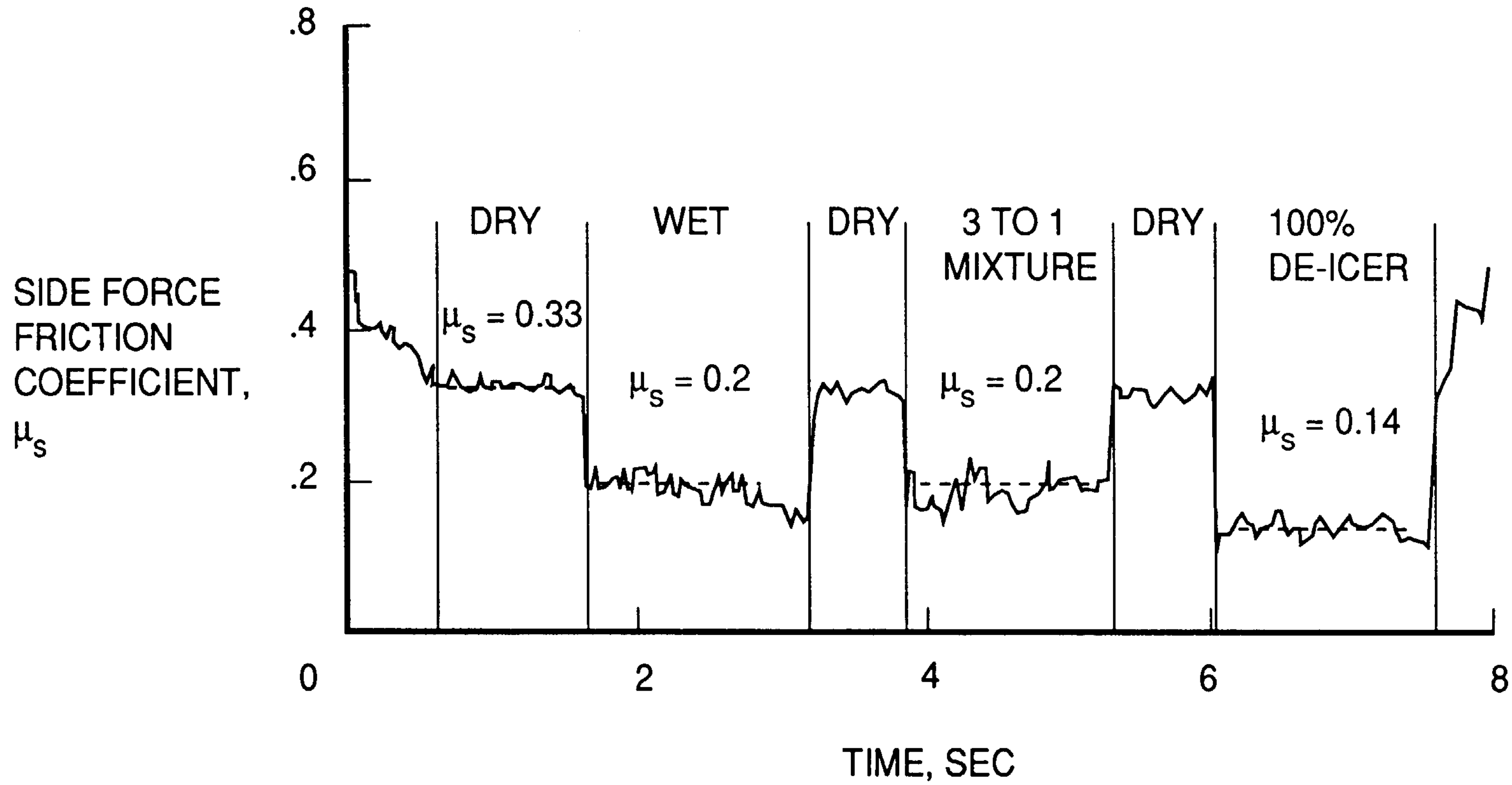


Figure 27 (b).

SPACECRAFT DYNAMICS BRANCH

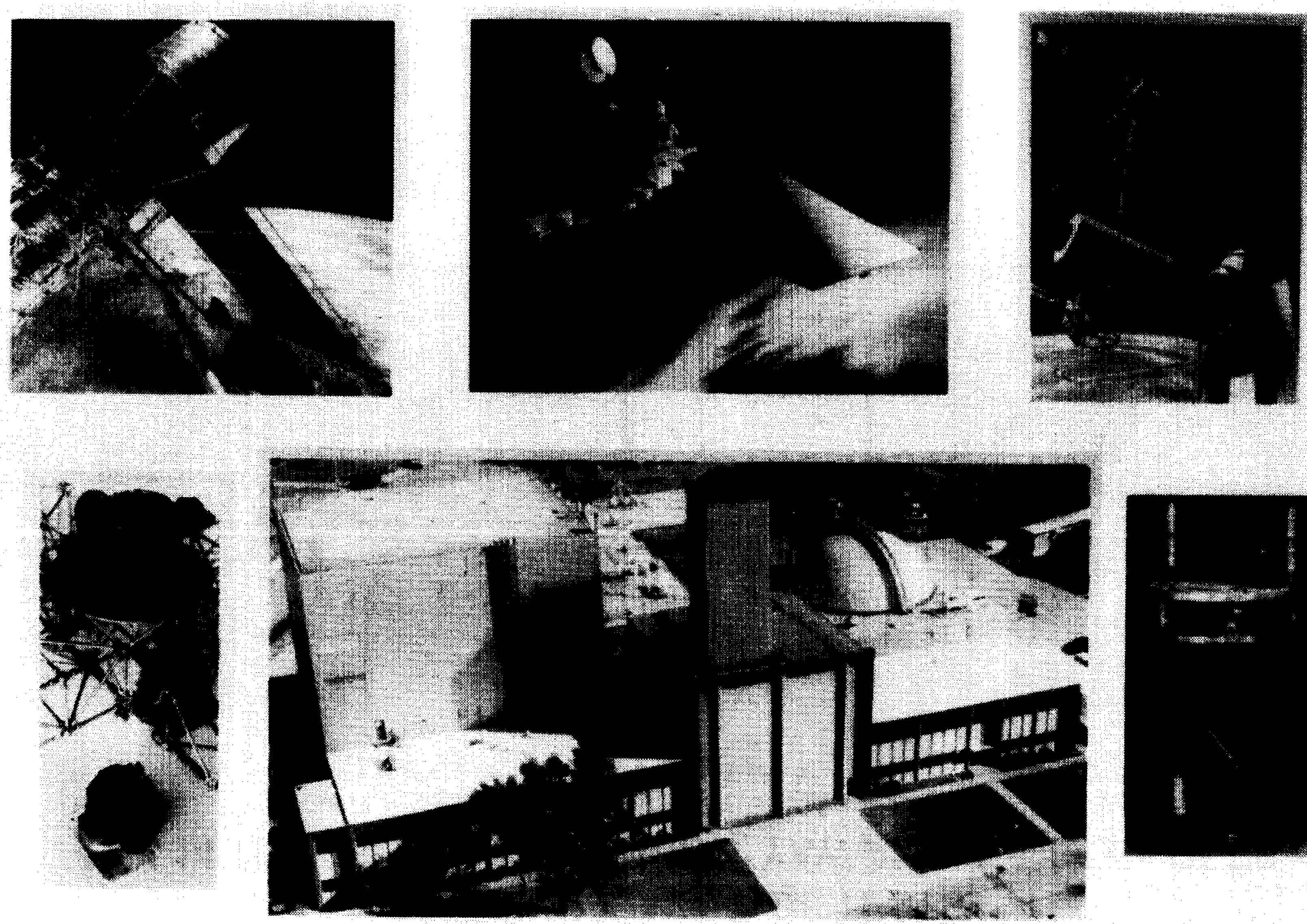


Figure 28.

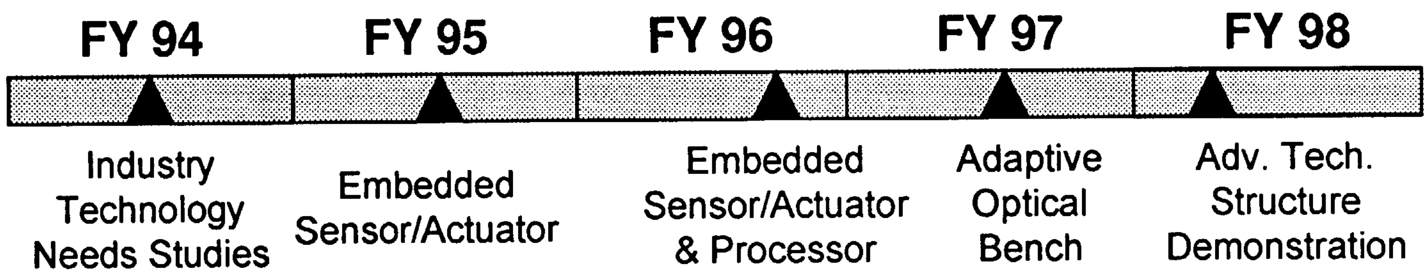
SPACECRAFT DYNAMICS FUTURE PLANS (FY94-98)

GOAL

- Develop, demonstrate, and transfer new structures, structural dynamics, and materials technologies for NASA and commercial space programs

KEY OBJECTIVES

- Enhance the dynamic response characteristics of primary spacecraft bus structures



- Control the transmitted disturbances and response of spacecraft attached solar arrays, antennas, and booms

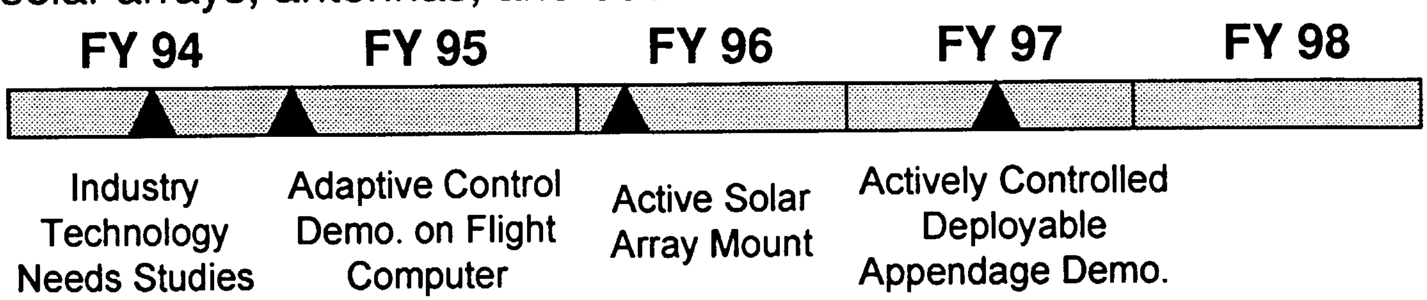


Figure 29.

SPACECRAFT SIZE AFFECTS POINTING PERFORMANCE

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Spacecraft Dynamics Branch

Peiman G. Maghami and Sean P. Kenny
Spacecraft Controls Branch

RTOP 585-03-11

Research Objective: To assess the effects of spacecraft size on the precision pointing capability needed for remote sensing.

Approach: A comparison of pointing jitter levels was made for three different size spacecraft. In all three cases, the disturbance was due to the same instrument. The metric used to compare the spacecraft was the ability to point the spacecraft's navigation base.

Accomplishment Description: The three spacecraft used in this study were either directly from, or derivatives of, the Earth Observing System (EOS) series of spacecraft. EOS A, designed in 1990, was the largest spacecraft. EOS AM-1, designed in 1991 by down sizing EOS A, has only one-tenth the rotational inertia of EOS A. The third spacecraft was created for this study by down sizing EOS AM-1. This smaller spacecraft has one-sixth the rotational inertia of EOS AM-1. Pointing performance data for EOS A was taken from a previous study performed by the prime contractor. Performance data for the EOS AM-1 and the smaller spacecraft were computed from a state-space simulation of the closed-loop dynamics. Both rigid and flexible body motion of the platforms were modeled. Jitter, the peak-to-peak variation in the response, was computed from the time histories using various time window lengths. The attached figure indicates the jitter pointing performance of the three spacecraft due to the same disturbance. The largest spacecraft , EOS A, had the lowest jitter level. EOS AM-1 had nearly an order of magnitude higher jitter than EOS A. This increase in jitter is directly related to the decrease in rotational inertia. The smallest spacecraft has the poorest pointing performance. Again, the increased jitter levels are proportional to the decrease in rotational inertia. In these results, the jitter level is inversely related to the spacecraft size (rotational inertia) because the disturbance primarily excited rigid-body response. Jitter levels due to disturbances which excite flexible-body response were found to either increase or decrease as the size of the spacecraft was varied. It was found that if changes in spacecraft size tuned one or more flexible vibration modes to the frequency of the disturbance, significant increases in jitter occurred.

Significance: This study has identified the need to consider the degradation in pointing performance associated with smaller spacecraft. For the same disturbance, a smaller spacecraft has increased jitter due to rigid-body response. No direct statement can be made on the influence of spacecraft size on the flexible-body response as jitter may either increase or decrease depending on the disturbance frequencies.

Future Plans: Detailed assessment of pointing jitter is planned for the EOS AM-1 spacecraft. In addition, statistical approaches to jitter performance prediction will be pursued to provide jitter sensitivity information with respect to uncertainty in the structural, controls, and disturbance models.

Figure 30 (a).

SPACECRAFT SIZE AFFECTS POINTING PERFORMANCE

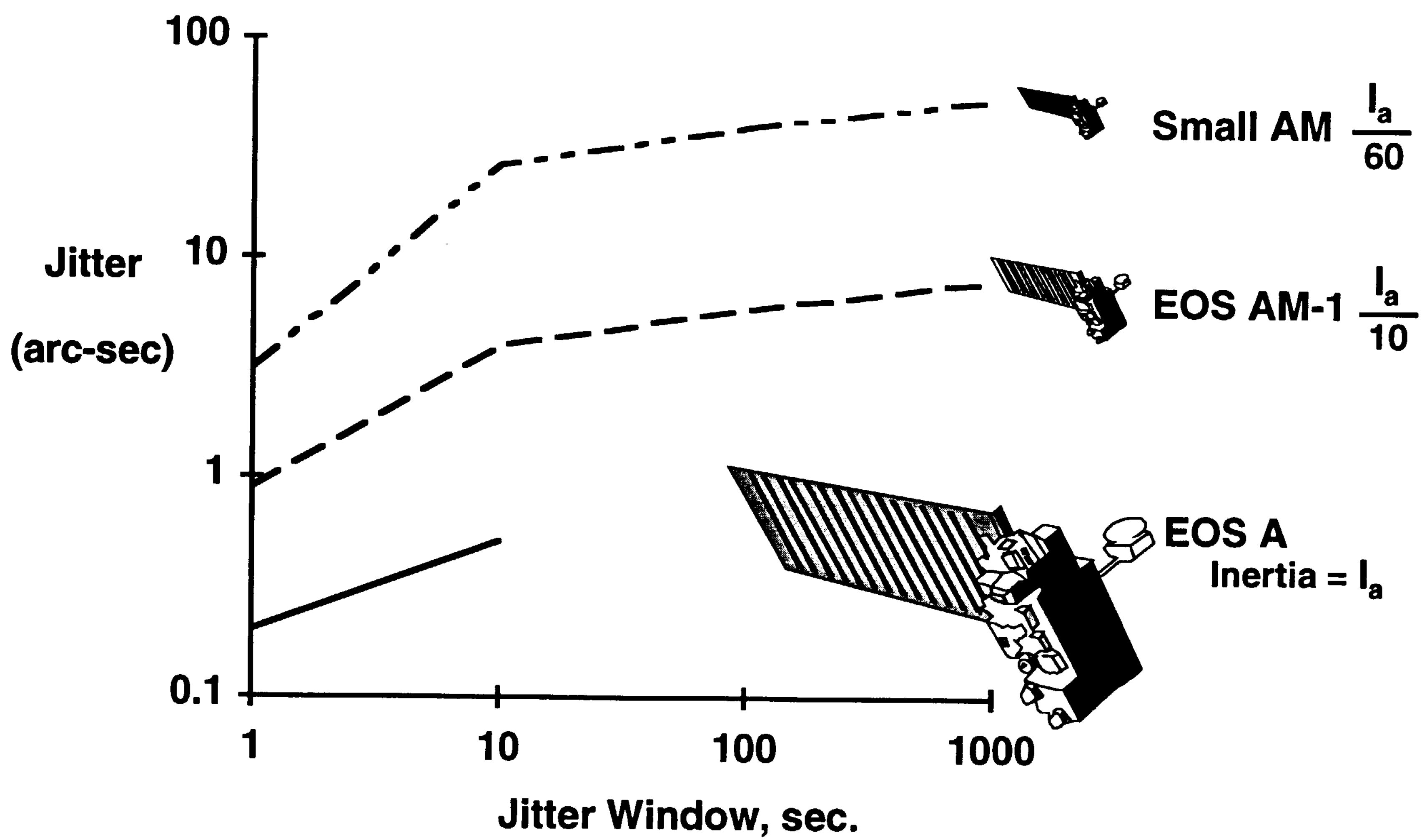


Figure 30 (b).

MARTIN MARIETTA VISCOELASTIC DAMPER STRUT TESTING ON THE PHASE-2 CEM TESTBED

Eric Schmitz, Chris Voth, Kenneth Richards, Jeffrey Sulla and Dean Sparks, Jr.
Martin Marietta Astronautics Group, Lockheed Engineering and Sciences Company, and Spacecraft Controls Branch

RTOP 585-03-11-04

Research Objective: There are two generic ways of suppressing vibrational motions of space structures: either by passively supplementing the inherent damping in the structures, or by using on-board actuators and sensors to actively control the structures' vibrational motion. The objective of this research is to investigate the benefits of combining passive and active vibration suppression control on space structures.

Approach: The Phase-2 CEM truss structure was selected as the testbed for this activity. First, open-loop frequency response function (FRF) measurements were taken on the nominal Phase-2 CEM, to verify and/or to update the analytical model of the CEM. Several closed-loop H2/LQG controllers were then tested to measure both their performances in suppressing vibrations, and their stability margins, i.e., the margins by which the controller gains could be increased before instabilities occur. Next, to study the effects of passive damping treatment, 60 viscoelastic damper struts were installed in the Phase-2 CEM (see top figure). These damper struts were designed to be interchangeable with the regular Phase-2 CEM struts and be compatible with the connecting node ball adapter hardware. The damper struts were fabricated in two sizes, one size for longeron members, the other for the longer diagonal members. Each damper strut houses Dyad 606, the viscoelastic material intended to dissipate the strain energy in the strut. After the installation of these damper struts, the same open-loop FRF and closed-loop controllers, previously tested on the nominal Phase-2 CEM, were repeated to determine the passive damping effectiveness. In addition, several new controllers, specifically designed for the Phase-2 CEM with the damper struts in place, were tested to investigate the benefits of combining passive and active control.

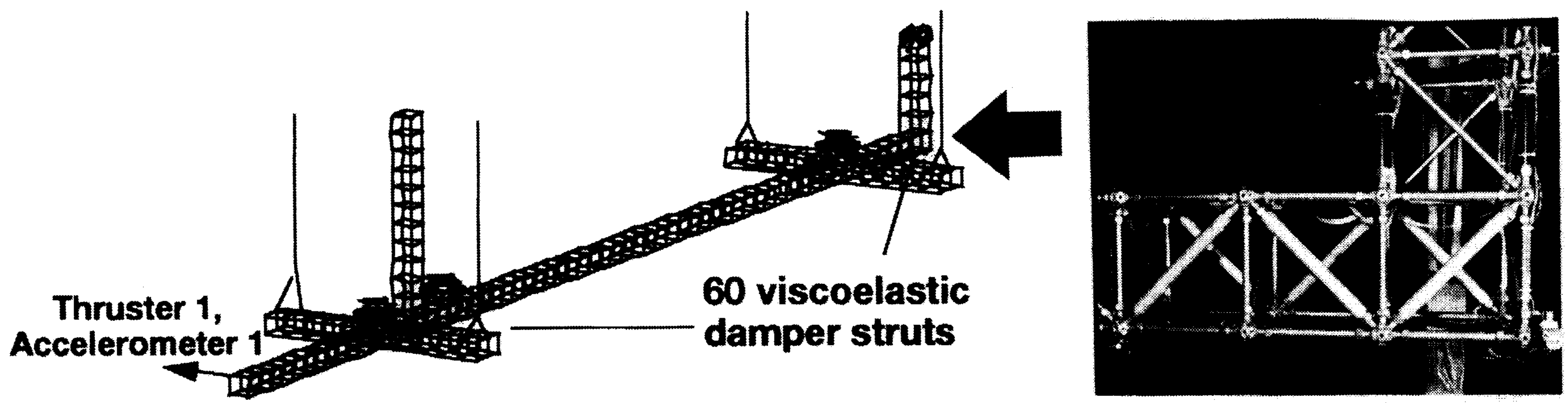
Accomplishments: Tests with the damper struts in the Phase-2 CEM testbed have successfully demonstrated the effectiveness of passive damping. The bottom figure shows a comparison of sample FRFs taken from the Phase-2 CEM, with and without the damper struts in place; the damper struts have reduced the open-loop peak magnitudes by 10-20 dB. In addition, closed-loop test results have shown that the damper struts do increase the stability margins of the controllers designed for the nominal Phase-2 CEM. The same figure also shows that by combining passive and active control, further significant reductions in the peak magnitudes can be obtained. Finally, the modeling of the dampers in the Phase-2 CEM was also successful, in terms of matching analytical and measured FRF and singular value plots. The predicted passive damping values were within 10 percent of the actual damping values, for the primary modes of interest.

Significance: This activity has successfully demonstrated the benefits of using passive damping for vibration suppression on space structures, both alone and in combination with active controllers.

Future Plans: These damper struts will be used in the planned Phase-3 CEM testbed, since the structure will be built using the existing Phase-2 strut and node ball adapter hardware. The damper struts will also be used in vibration isolation tests, both on the Phase-3 CEM and other test articles.

Figure 31 (a).

Martin Marietta Viscoelastic Damper Strut Testing on the Phase-2 CEM Testbed



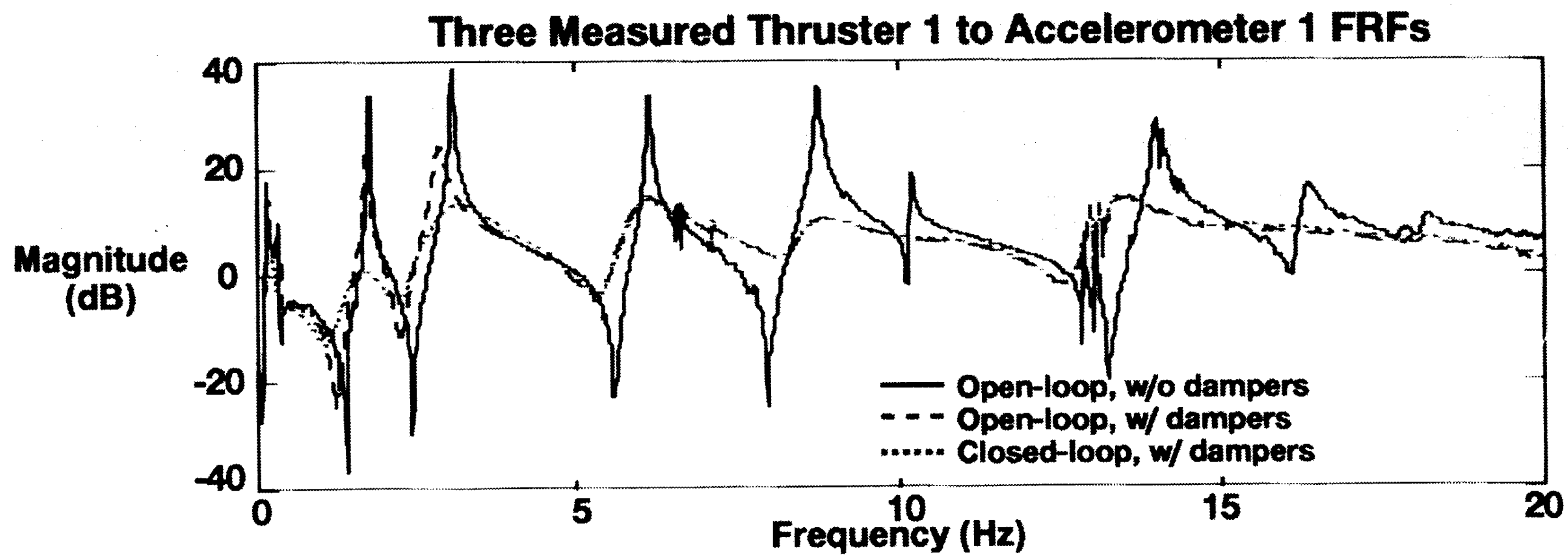


Figure 31 (b).

EIGENSYSTEM REALIZATION ALGORITHM (ERA) MEETING
NASA AND INDUSTRY DYNAMIC TESTING NEEDS

Richard S. Pappa

RTOP 585-03-11

Research Objective: To develop and improve the eigensystem realization algorithm (ERA) for modal identification - natural vibration frequencies, damping, mode shapes, and modal masses - of complex structures.

Approach: The ERA provides a means for conducting multiple-input/multiple-output, time-domain analyses of either frequency response or free decay vibration data. In addition, a reduced state-space model suitable for control design can be obtained by using ERA. The approach was to improve the accuracy and efficiency of ERA as well as to add additional capabilities such as accuracy indicators. These and other software improvements have been incorporated into ERA for use on a popular computer platform (VAX) with interfaces to commercial codes including SDRC I-DEAS and MATLAB.

Accomplishment Description: ERA performance with complex structures was demonstrated initially using in-house experiments and Galileo spacecraft data. Results satisfied structural-test requirements for validation of finite-element models. Subsequent applications involved model development for active vibration control. State-space models of multiple-input/multiple-output configurations were successfully obtained. Accurate identification of many modes over wide frequency bandwidths, including intervals of high modal density, was regularly demonstrated. Publication of in-house results prompted many requests for this software. A total of 54 requests have been received consisting of 23 from industry, 16 from other government labs, and 15 from academia. Many software improvements have resulted from these application experiences.

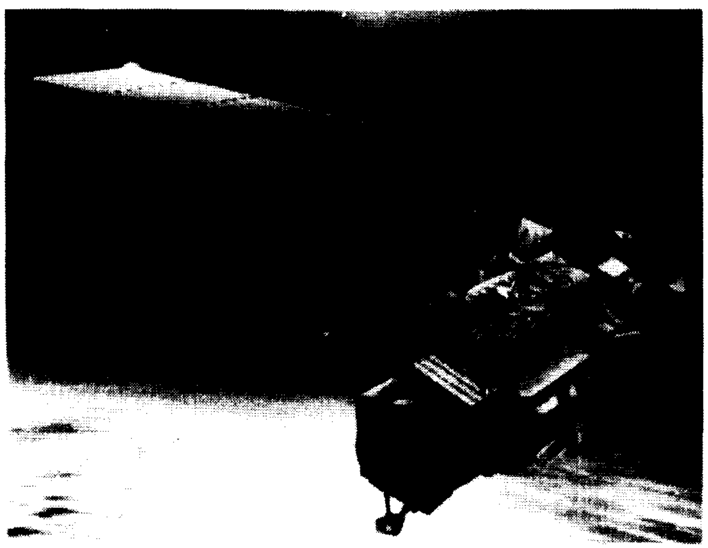
Significance : The on-orbit dynamic behavior of future large spacecraft, such as Space Station Freedom, can significantly affect mission performance. Unexpected vibration can disrupt microgravity experiments, remote-sensing measurements, and the operation of control systems. Furthermore, multiple payloads can interact through flexible adjoining structure. Modal identification tests are required for verification of predicted dynamic characteristics. Because of their size and complexity, these structures pose unprecedented challenges to modal identification technology. These anticipated future spacecraft have served as the research focus for development of ERA. Successful development of this technology permits application to a broad spectrum of less-complicated structures such as the wind turbine shown in the figure. Sandia Labs used ERA to determine the damping levels of blade modes for fatigue life prediction.

Future Plans : A comprehensive user's guide (NASA TM) is being written to document the ERA software. There has been considerable interest by modal-identification software companies to incorporate ERA into their product lines.

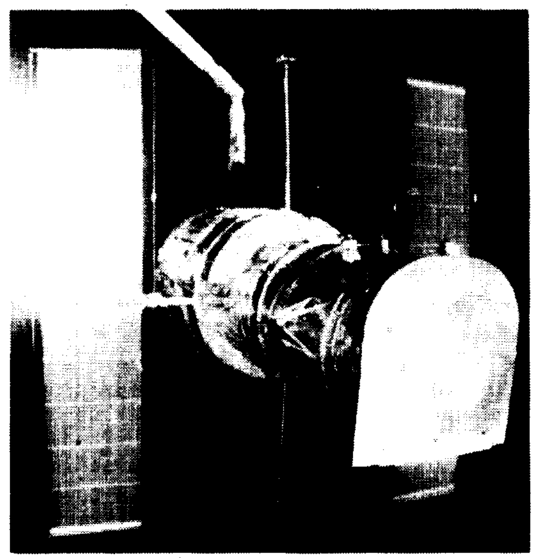
Figure 32 (a).

EIGENSYSTEM REALIZATION ALGORITHM (ERA) MEETING NASA AND INDUSTRY DYNAMIC TESTING NEEDS

- Used for identification of system dynamic properties
- Proven effectiveness with complex vibration characteristics
- 54 requests for software



UARS
(GE)



Hubble Space
Telescope
(GSFC)

Wind Turbine
(Sandia Labs)

Figure 32 (b).

STATE SPACE FREQUENCY DOMAIN IDENTIFICATION TOOLS

Lucas G. Horta and Jer-Nan Juang
Spacecraft Dynamics Branch

RTOP 583-03-11

Objective: System identification is commonly used for model correlation, trouble-shooting, control design, health monitoring and many other applications. Computers allow fast conversion/compression of time response data to spectral and/or frequency response information which is then used in the identification process. One objective of this work is to develop tools to convert frequency data into useful mathematical models. A second objective is to understand the advantages and limitations of these procedures and how they compare to time domain approaches.

Approach: The algorithm solves for a state-space model in two steps; first, frequency data is fitted with a model in matrix polynomial form, and second, the matrix polynomial model is used with realization theory for order determination and a state-space realization. One advantage of this approach is the ability to recover state space models from sections of data with minimum window distortions.

Accomplishments: Formulations for system identification using matrix polynomials have been implemented. These representations allow compression of frequency data into a reduced set of matrices used to compute smoothed pulse responses. A number of variations in the matrix polynomial solution approach have shown significant changes in the identification results. Numerical and experimental results indicated that the matrix polynomial description using frequency data smoothed the estimated transfer function and therefore facilitated model realization. Unevenly spaced frequency responses are easily concatenated from multiple experiments to recover a model for the frequency range analyzed. The cartoon, shown in the accompanying figure, depicts two tests made with different frequency resolution and analysis ranges being combined into a single model. This operation is rather simple using matrix polynomials because one model is fitted to the full frequency range. MATLAB software is currently available that automates the identification procedure.

Significance: A two step approach for estimating state space models from frequency data has been developed. Although examples have concentrated on structural identification this approach is applicable to any problem involving identification from frequency data. Data obtained at different sampling rates and from different tests is easily combined using this approach. It is a convenient tool to help analyst decipher complicated data.

Future Plans: Formal documentation of the MATLAB algorithms is practically completed. Software is currently under limited distribution, but plans are to continue software enhancements as time permits.

Figure 33 (a).

STATE SPACE FREQUENCY DOMAIN IDENTIFICATION TOOLS

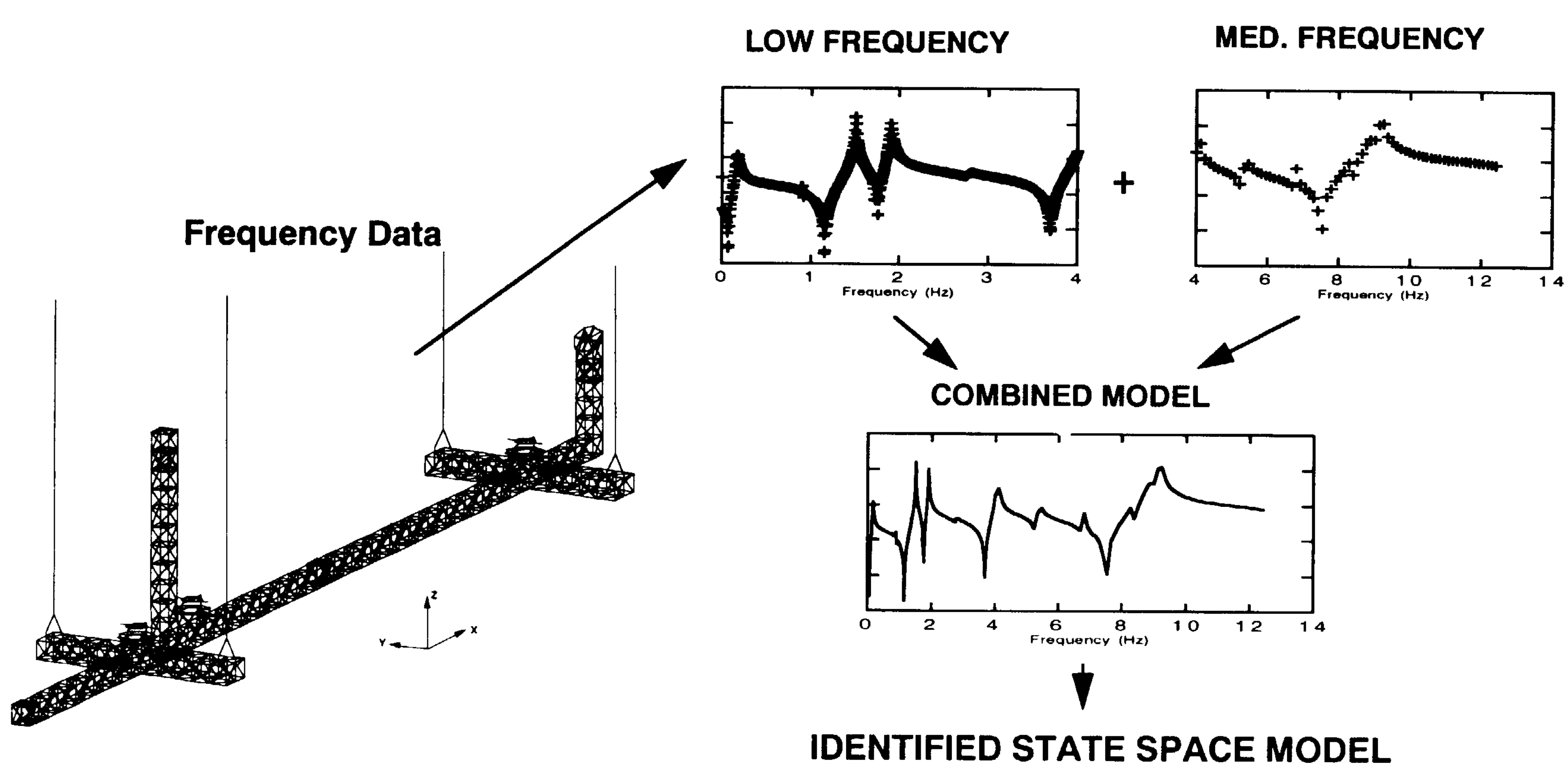


Figure 33 (b).

AEROELASTIC ANALYSIS AND OPTIMIZATION
F. Y. 1994 PLANS

- Provide support for SDyD Benchmark Models Program
- Complete and document TDT turbulence characterization
- Apply viscous version of CAP-TSD to cases of transonic limit cycle oscillation
- Develop a gridless CFD method for application to computational aeroelasticity
- Complete design of rigid HSCT model and modified PAPA mount for Benchmark Models Program
- Develop methods for using nonlinear aerodynamics in aeroservoelastic analysis and design
- Apply automatic differentiation to produce capability for sensitivity analysis of helicopter rotor blade hover performance
- Develop integrated aerodynamic performance-acoustic optimization procedure for rotor blades
- Complete dynamic optimization procedure to minimize effects of uncertainties in loads and properties
- Formulate an integrated aerodynamic and structural design problem for an HSCT configuration
- Develop alternate optimization strategies and formulations for incorporating nonlinear aerodynamic and finite element structural analysis procedures into the FIDO optimization system
- Demonstrate new method for computing flutter speed derivatives with respect to structural and shape variables, incorporating advanced aerodynamics
- Develop method for integrated design to structure-control system for minimum sensitivity to uncertainties

Figure 34.

AEROELASTICITY
F. Y. 1994 PLANS

- Complete open-loop test of Benchmark active-controls model
- Complete tests of PARTI model to demonstrate FSS using piezoelectric materials
- Continue flutter tests of full-span A/F-18E/F model
- Complete flutter clearance tests of full-span Cessna Citation X model
- Complete tests of complex NASP engine model
- Complete flutter and buzz tests of Wright Lab NASP vertical-fin model
- Complete transonic flutter tests of Gulfstream V model
- Complete tests of semispan rigid HSCT model
- Complete initial evaluation of rotating strain-gage balance on ARES testbed
- Complete tests of the optimization validation rotor blades on ARES testbed
- Complete refurbishment of full-span flexible SST model
- Initiate refurbishment of V-22 aeroelastic model
- Initiate program to investigate neural networks for adaptive FSS
- Initiate design for modifications to convert TDT to alternate heavy gas
- Install and initiate the implementation of the next generation UNIX-based ModComp DAS

Figure 35.

LANDING AND IMPACT DYNAMICS
F. Y. 1994 PLANS

- Expand energy-absorbing beam designs for composite subfloors through FAA Interagency Agreement
- Initiate second phase of scaling effect on progressive failure of composites
- Conduct tests on innovative textile preforms and RTM composite subfloor specimens from ACT program
- Conduct full-scale crash test of unmodified Lear Fan aircraft
- Investigate feasibility of fabricating a scaled composite fuselage section using subply composite material as part of new GA initiative
- Conduct friction, wear, and mechanical properties studies of aircraft tires in support of industry request on ALDF
- Bring runway simulator on-line and conduct tests with A-6 main gear in support of active control landing gear program
- Develop smart orifice active control landing gear concept
- Conduct initial experimental study of tire slip under static loading conditions to understand friction and wear mechanism within tire footprint
- Develop tire damping algorithms which are computationally efficient for tire modeling

Figure 36.

SPACECRAFT DYNAMICS
F. Y. 1994 PLANS

- Earth Observation Spacecraft Technology
  - Develop low-frequency jitter reduction experiment design for EOS AM-1 spacecraft
  - Develop high-bandwidth jitter suppression system for EOS applications
  - Conduct multi-instrument jitter reduction tests on EOS laboratory simulation model
  - Co-sponsor contract study of structural design trades and multi-application components for small Earth-observing spacecraft

- Space and Planetary Spacecraft Technology
  - Co-sponsor contract study of structural design trades and multi-application components for small space-observing spacecraft
  - Dual-use technology transfer of variable geometry truss manipulator design

Figure 37.

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13. ABSTRACT *(Maximum 200 words)*

The purpose of this paper is to present the Structural Dynamics Division's research accomplishments for F.Y. 1993 and research plans for F.Y. 1994. The work under each Branch (technical area) is described in terms of highlights of accomplishments during the past year and highlights of plans for the current year as they relate to 5-year plans for each technical area. This information will be useful in program coordination with other governmen organizations and industry in areas of mutual interest.

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